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JC07 Rec'd PCT/PTO 2 0 NOV 2001

FORM PTO-1390 (REV 10-94) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 8436.88USWO

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5): Unknown 09/979586

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/IB00/00739	May 22, 2000	May 20, 1999

TITLE OF INVENTION

VARIABLE PHASE SHIFTER

APPLICANT(S) FOR DO/EO/US

DU TOIT et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US)
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [X] have not been made and will not be made.

8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. [X] An unsigned oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).

10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. [X] A FIRST preliminary amendment, Marked-up Copy of Claims.
    [ ] A SECOND of SUBSEQUENT preliminary amendment.

14. [ ] A substitute specification.

15. [ ] A change of power of attorney and/or address letter.

16. [X] Other items or information: PCT/IPEA/416; PCT/IPEA/409; PCT/ISA/210

JC10 Rec'd PCT/PTO 2 0 NOV 2001

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
Unknown 09/979586	PCT/IB00/00739	8436.88USWO

17. [X] The following fees are submitted:

CALCULATIONS PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492(a) (1)-(5)):

Search Report has been prepared by the EPO or JPO **$890.00**

International preliminary examination fee paid to USPTO (37 CFR 1.492(a)(1)) **$710.00**

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) **$740.00**

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(3)) paid to USPTO **$1040.00**

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) **$100.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =				**$1040.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				**$**	
CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE	
Total claims	72	-20 =	52	X **$18.00**	**$936.00**
Independent claims	7	-3 =	4	X **$84.00**	**$336.00**
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ **$260.00**	**$**
TOTAL OF ABOVE CALCULATIONS =					**$2312.00**
Reduction by 1/2 for filing by small entity, if applicable. Small entity status is claimed pursuant to 37 CFR 1.27					**$**
SUBTOTAL =					**$2312.00**
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f).				+	**$**
TOTAL NATIONAL FEE =					**$2312.00**
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property				+	**$**
TOTAL FEES ENCLOSED =					**$2312.00**
				Amount to be: refunded	**$**
				charged	**$**

a. [X] Check(s) in the amount of $2312.00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 13-2725.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:
Brian H. Batzli
MERCHANT & GOULD
P.O. Box 2903
Minneapolis, MN 55402-0903

SIGNATURE: _____

NAME: Brian H. Batzli

REGISTRATION NUMBER: 32,960

IN THE CLAIMS

Claim 3. (amended) A variable phase shifter according to claim 1 wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

Claim 4. (amended) A variable shifter according to claim 2 wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

Claim 5. (amended) A variable phase shifter according to claim 1, further comprising a conductive ground plane arranged on at least one side of the signal conductors.

Claim 7. (amended) A variable phase shifter according to claim 5 wherein the ground plane has a first portion adjacent the first conductor, a second portion adjacent the second conductor, and a step between the first and second portions.

Claim 8. (amended) A variable phase shifter according to claim 5 wherein the signal conductors each have substantially planar surfaces which face the [or each] ground plane.

Claim 9. (amended) A variable phase shifter according to claim 5 wherein the ground plane has one or more substantially planar surface portions facing the first and second signal conductors.

Claim 10. (amended) A variable phase shifter according to claim 5 wherein the ground plane and the first and second signal conductors each have a respective width transverse to a direction of signal propagation, and wherein the width of the ground plane is more than three times greater than the width of each of the signal conductors.

Claim 11. (amended) A variable phase shifter according to claim 5 wherein the ground plane is formed from a substantially planar sheet of conductive material.

Claim 15. (amended) A variable phase shifter according to claim 12 wherein the signal conductor with the oxide coating is formed from aluminum or an alloy thereof.

Claim 16. (amended) A variable phase shifter according to claim12 wherein at least one of the signal conductors has a lubricating coating formed on a surface thereof.

Claim 18. (amended) A variable phase shifter according to claim 12 wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

Claim 20. (amended) A variable phase shifter according to claim 1 further comprising a third signal conductor, wherein the second signal conductor has a first arm coupled to the first signal conductor and a second arm coupled to the third signal conductor whereby the second signal conductor provides a transmission path between the first and third signal conductors, and wherein the second signal conductor and the first and third signal conductors are relatively moveable to vary the physical length of the transmission path.

22. (amended) A variable phase shifter according to claim 1wherein the second signal conductor is separated from the first signal conductor by a dielectric.

25. (amended) A variable phase shifter according to claim 23 wherein the dielectric material is in contact with both signal conductors whereby the dielectric material provides a sliding bearing surface when the signal conductors are relatively moved.

28. (amended) A phase shifter according to claim 26 further comprising a coaxial cable having an inner conductor and an outer conductor, wherein the inner conductor is connected to one of the conductive paths.

29. (amended) A variable phase shifter according to claim 1, wherein the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 400 MHz, and an upper limit equal to or less than 3 GHz.

31. (amended) A power splitter/combiner comprising three or more signal terminals and a variable phase shifter according to claim 1 coupled between two of the signal terminals.

33. (amended) A phased array antenna comprising at least two radiating elements; and a feed network for feeding relatively phase-shifted signals to the radiating elements, wherein the feed network comprises one or more variable phase shifters according to claim1.

37. (amended) A method according to claim 35 wherein the step of forming the ground plane includes the step of bending the sheet so as to form a step between a first portion adjacent the first conductor and a second portion adjacent the second conductor.

38. (amended) A method according to claim 35 wherein the step of providing the first and second signal conductors includes the step of forming each of the conductors from a substantially planar sheet of conductive material.

44. (amended) A method according to claim 41 wherein the anodisation process comprises immersing the conductor in an electrolyte and passing a current through the conductor with a current density greater than 2 amps /dm^2.

45. (amended) A method according to claim 40 further comprising the step of forming a lubricating coating on a surface of at least one of the signal conductors.

47. (amended) A variable phase shifter manufactured by the method of claim 35.

49. (new) A variable phase shifter comprising first and second coupled signal conductors providing a transmission path through the phase shifter, the signal conductors being relatively movable to vary the

physical length of the transmission path, wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

50. (new) A variable phase shifter according to claim 49, further comprising a conductive ground plane arranged on at least one side of the signal conductors.

51. (new) A variable phase shifter according to claim 50 further comprising a second ground plane arranged on an opposite side of the signal conductors.

52. (new) A variable phase shifter according to claim 50 wherein the ground plane has a first portion adjacent the first conductor, a second portion adjacent the second conductor, and a step between the first and second portions.

53. (new) A variable phase shifter according to claim 50 wherein the signal conductors each have substantially planar surfaces which face the ground plane.

54. (new) A variable phase shifter according to claim 50 wherein the ground plane has one or more substantially planar surface portions facing the first and second signal conductors.

55. (new) A variable phase shifter according to claim 50 wherein the ground plane and the first and second signal conductors each have a respective width transverse to a direction of signal propagation, and wherein the width of the ground plane is more than three times greater than the width of each of the signal conductors.

56. (new) A variable phase shifter according to claim 50 wherein the ground plane is formed from a substantially planar sheet of conductive material.

57. (new) A variable phase shifter according to claim 49 further comprising a third signal conductor, wherein the second signal conductor has a first arm coupled to the first signal conductor and a second arm coupled to the third signal conductor whereby the second signal conductor provides a transmission path between the first and third signal conductors, and wherein the second signal conductor and the first and third signal conductors are relatively moveable to vary the physical length of the transmission path.

58. (new) A variable phase shifter according to claim 57 wherein the first and second arms of the third signal conductor extend in substantially parallel directions.

59. (new) A variable phase shifter according to claim 49 wherein the second signal conductor is separated from the first signal conductor by a dielectric.

60. (new) A variable phase shifter according to claim 59 wherein the dielectric comprises a solid or liquid dielectric material.

61. (new) A variable phase shifter according to claim 60 wherein the dielectric comprises a dielectric coating on the first and/or the second signal conductor.

62. (new) A variable phase shifter according to claim 60 wherein the dielectric material is in contact with both signal conductors whereby the dielectric material provides a sliding bearing surface when the signal conductors are relatively moved.

63. (new) A variable phase shifter according to claim 49, wherein the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 400 MHz, and an upper limit equal to or less than 3 GHz.

64. (new) A variable phase shifter according to claim 63, wherein the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 800MHz, and an upper limit equal to or less than 2.5 GHz.

65. (new) A variable phase shifter according to claim 50 further comprising a conductive ground strip arranged on an opposite side of the signal conductors, the ground strip having a width transverse to a direction of signal propagation which is less than the width of the ground plane.

66. (new) A variable phase shifter according to claim 49 wherein the first and second conductors are capacitively coupled to each other.

67. (new) A power splitter/combiner comprising three or more signal terminals and a variable phase shifter according to claim 49 coupled between two of the signal terminals.

68. (new) A power splitter/combiner according to claim 67 further comprising an impedance matcher coupled between two of the signal terminals.

69. (new) A phased array antenna comprising at least two radiating elements; and a feed network for feeding relatively phase-shifted signals to the radiating elements, wherein the feed network comprises one or more variable phase shifters according to claim 49.

70. (new) A cellular telecommunications system comprising a phased array antenna according to claim 69.

71. (new) A variable phase shifter manufactured by the method of claim 39.

72. (new) A variable phase shifter manufactured by the method of claim 40.

REMARKS

The above preliminary amendment is made to remove multiple dependencies from claims 4, 5, 7-11, 15, 16, 18, 20, 22, 25, 28, 29, 31, 33, 37, 38, 44, 45 and 47.

A new abstract page is supplied to conform to that appearing on the publication page of the WIPO application, but the new Abstract is typed on a separate page as required by U.S. practice.

Applicants respectfully request that the preliminary amendment described herein be entered into the record prior to calculation of the filing fee and prior to examination and consideration of the above-identified application.

If a telephone conference would be helpful in resolving any issues concerning this communication, please contact Applicants' primary attorney-of record, Brian H. Batzli (Reg. No. 32,960), at 612.336.4755.

Respectfully submitted,

MERCHANT & GOULD P.C.
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Dated: November 20, 2001

By _____
Brian H. Batzli
Reg. No. 32,960

BHBATZLI/kas

Marked-Up Copy of Claims

Claim 3. A variable phase shifter according to claim 1 [comprising first and second coupled signal conductors providing a transmission path through the phase shifter, wherein the signal conductors are relatively movable to vary the physical length of the transmission path; and] wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

Claim 4. A variable shifter according to claim [3 and claim 1 or] 2 wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

Claim 5. A variable phase shifter according to [any one of the preceding] claim[s] 1, further comprising a conductive ground plane arranged on at least one side of the signal conductors.

Claim 7. A variable phase shifter according to claim 5 [or 6] wherein [one or both of] the ground plane[s] has a first portion adjacent the first conductor, a second portion adjacent the second conductor, and a step between the first and second portions.

Claim 8. A variable phase shifter according to [any of] claim[s] 5 [to 7] wherein the signal conductors each have substantially planar surfaces which face the [or each] ground plane.

Claim 9. A variable phase shifter according to [any one of] claim[s] 5 [to 8] wherein the [or each] ground plane has one or more substantially planar surface portions facing the first and second signal conductors.

Claim 10. A variable phase shifter according to [any one of] claim[s] 5 [to 9] wherein the ground plane and the first and second signal conductors each have a respective width transverse to a direction of signal propagation, and wherein the width of the ground plane is more than three times greater than the width of each of the signal conductors.

Claim 11. A variable phase shifter according to [any one of] claim[s] 5 [to 10] wherein the ground plane is formed from a substantially planar sheet of conductive material.

Claim 15. A variable phase shifter according to [any one of] claim[s] 12 [to 14] wherein the signal conductor with the oxide coating is formed from aluminum or an alloy thereof.

Claim 16. A variable phase shifter according to [any one of] claim[s] 12 [to 15] wherein at least one of the signal conductors has a lubricating coating formed on a surface thereof.

Claim 18. A variable phase shifter according to [any one of] claim[s] 12 [to 17] wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

Claim 20. A variable phase shifter according to [any one of the preceding] claim[s] 1 further comprising a third signal conductor, wherein the second signal conductor has a first arm coupled

to the first signal conductor and a second arm coupled to the third signal conductor whereby the second signal conductor provides a transmission path between the first and third signal conductors, and wherein the second signal conductor and the first and third signal conductors are relatively moveable to vary the physical length of the transmission path.

22. A variable phase shifter according to [any one of the preceding] claim[s] 1 wherein the second signal conductor is separated from the first signal conductor by a dielectric.

25. A variable phase shifter according to claim 23 [or 24] wherein the dielectric material is in contact with both signal conductors whereby the dielectric material provides a sliding bearing surface when the signal conductors are relatively moved.

28. A phase shifter according to claim 26 [or 27] further comprising a coaxial cable having an inner conductor and an outer conductor, wherein the inner conductor is connected to one of the conductive paths.

29. A variable phase shifter according to [any one of the preceding] claim[s] 1, wherein the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 400 MHz, and an upper limit equal to or less than 3 GHz.

31. A power splitter/combiner comprising three or more signal terminals and a variable phase shifter according to [any one of the preceding] claim[s] 1 coupled between two of the signal terminals.

33. A phased array antenna comprising at least two radiating elements; and a feed network for feeding relatively phase-shifted signals to the radiating elements, wherein the feed network comprises one or more variable phase shifters according to [any one of] claim[s] 1 [to 30 and/or a power splitter/combiner according to claim 31 or 32].

37. A method according to claim 35 [or 36] wherein the step of forming the ground plane includes the step of bending the sheet so as to form a step between a first portion adjacent the first conductor and a second portion adjacent the second conductor.

38. A method according to [any one of] claim[s] 35 [to 37] wherein the step of providing the first and second signal conductors includes the step of forming each of the conductors from a substantially planar sheet of conductive material.

44. A method according to [any one of] claim[s] 41 [to 43] wherein the anodisation process comprises immersing the conductor in an electrolyte and passing a current through the conductor with a current density greater than 2 amps /dm^2.

45. A method according to [any one of] claim[s] 40 [to 44] further comprising the step of forming a lubricating coating on a surface of at least one of the signal conductors.

47. A variable phase shifter manufactured by the method of [any one of] claim[s] 35 [to 46].

ABSTRACT

A variable phase shifter comprising first and second coupled signal conductors (6, 7, 17) providing a transmission path through the phase shifter. The signal conductors are relatively movable to vary the physical length of the transmission path. The first signal conductor comprises a pair of electrically parallel arms (6,7), and the second signal conductor (17) is arranged between the arms of the first signal conductor. A ground plane (1) is arranged on one side of the signal conductors.

S/N unknown

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	DU TOIT et al.	Serial No.:	unknown
Filed:	concurrent herewith	Docket No.:	8436.88USWO
Title:	VARIABLE PHASE SHIFTER		

CERTIFICATE UNDER 37 CFR 1.10
'Express Mail' mailing label number: EL669945315US
Date of Deposit: November 20, 2001
I hereby certify that this correspondence is being deposited with the United States Postal Service 'Express Mail Post Office To Addressee' service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C . 20231.

By: _____
Name: Chris Stordahl

PRELIMINARY AMENDMENT

Box PCT
Assistant Commissioner for Patents
Washington, D. C. 20231

Dear Sir:

In connection with the above-identified application filed herewith, please enter the following preliminary amendments, based on claims amended in prosecution of the international application and published in the International Preliminary Examination Report, a copy of which is enclosed herewith:

IN THE ABSTRACT

Insert the attached Abstract page into the application as the last page thereof.

IN THE SPECIFICATION

A courtesy copy of the present specification is enclosed herewith. However, the World Intellectual Property Office (WIPO) copy should be relied upon if it is already in the U.S. Patent Office.

VARIABLE PHASE SHIFTER

Field of the Invention

The present invention relates to a variable phase shifter, and to a method of manufacturing a variable phase shifter.

Background of the Invention

Phase shifters are a necessary component of phased array antennas. There is a demand for low cost, high reliability, and low complexity phase shifters to be incorporated into phased array antennas.

A number of methods for signal phase shifting have been used to date. Semiconductor devices, such as PIN diodes, have been used. These are electronically controllable switches used to change an RF circuit so as to achieve a desired phase shift but do not allow continuous phase shifting, can cause intermodulations, are power limited and require complex control circuitry. Phase shifters which vary the dielectric constant of a material provided between a conductor and a ground plane have also been employed.

Another conventional method employs first and second coupled signal conductors providing a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path. An example of a phase shifter of this type is described in US-A-5801600. One of the difficulties with this method is to ensure good signal coupling between the conductors so as to minimise intermodulations at the boundary between the conductors.

Summary of the Invention

According to a first aspect of the present invention there is provided a variable phase shifter comprising first and second capacitively coupled signal conductors providing a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path, wherein the first signal conductor comprises a pair of electrically parallel arms, and wherein the second signal conductor is arranged between the arms of the first signal conductor.

This arrangement has a number of advantages. Firstly, by interposing the second signal conductor between the arms of the first signal conductor, the electric coupling between the first and second conductors is maximised. This enables the transmission path length to be varied over a wide range. Secondly, the conductor arrangement results in a branched transmission path which has high symmetry. Thirdly, the spacing between the arms of the first signal conductor can be accurately controlled, and adjusted if necessary.

Preferably support means are arranged on opposite sides of the first signal conductor so as to maintain a maximum spacing between the arms of the first signal conductor. This keeps the first and second signal conductors in close proximity to maximise electrical coupling between the conductors, and enables the line impedance to be precisely controlled. The first signal conductor may be received in an aperture in a support rib, with the opposite sides of the aperture providing the support means. Alternatively a pair of ribs may be provided, one having a recess which receives the conductor, with the support means being provided by the base of the recess and an edge of the other rib.

Preferably a conductive ground plane is arranged on at least one side of the signal conductors. The provision of a ground plane enables the signal to be

propagated in TEM or quasi-TEM mode. The ground plane may be connected to a floating voltage reference but is preferably electrically earthed. Preferably the ground plane is connected to the voltage reference (or to earth) at more than one point. This ensures that in use the voltage across the entire ground plane is substantially constant.

Only a single ground plane may be provided (known as a microstrip arrangement). Alternatively a second ground plane may be arranged on an opposite side of the signal conductors (a stripline arrangement). In a further alternative 'hybrid' arrangement, a relatively narrow ground strip may be arranged on an opposite side of the signal conductors.

It will be understood by those skilled in the art that the ground plane may or may not be entirely planar. However preferably the or each ground plane has one or more substantially planar surface portions facing the first and second signal conductors.

Preferably the width of the ground plane is significantly greater (for instance more than three times greater) than the width of each of the signal conductors (transverse to the direction of signal propagation).

In a preferred arrangement one or both of the ground planes has a first portion adjacent the first conductor, a second portion adjacent the second conductor, and a step between the first and second portions. This enables the line impedance presented by the first and second conductors to be controlled (ie by varying the distance between the ground plane and the signal conductors).

Typically the signal conductors have substantially planar surfaces which face the or each ground plane. This makes the signal conductors easy to manufacture (for instance by a process of stamping from a sheet) and

increases field homogeneity between the signal conductors and the ground plane.

Preferably the arms of the first signal conductor each have substantially planar coupling surfaces which are arranged on opposite sides of the second signal conductor and which lie substantially parallel with each other.

According to a second aspect of the invention there is provided a variable phase shifter comprising first and second coupled signal conductors providing a transmission path through the phase shifter, wherein the signal conductors are relatively movable to vary the physical length of the transmission path, and wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

The use of planar coupling surfaces makes the signal conductors easy to manufacture (for instance by a process of stamping from a sheet) and maximises coupling between the conductors.

The signal conductors may be C-shaped or L-shaped (as viewed in a cross-section taken across the direction of signal propagation) or may have interlocking grooves or steps. However in a preferred embodiment the signal conductors are strips formed from a sheet having a substantially rectangular cross-section.

The conductive material forming the signal conductors is typically a metal such as copper, brass or aluminium alloy.

In a preferred arrangement the phase shifter further comprises a third signal conductor, wherein the second signal conductor has a first arm coupled to the first signal conductor and a second arm coupled to the third signal conductor whereby the second signal conductor provides a transmission path

between the first and third signal conductors, and wherein the second signal conductor and the first and third signal conductors are relatively moveable to vary the physical length of the transmission path.

The arms of the second signal conductor may lie at an angle to each other (ie the second signal conductor may be V-shaped). However preferably the first and second arms of the second signal conductor extend in substantially parallel directions.

The first and third conductors may be moveable but preferably they are fixed and the second signal conductor is moveable (in the manner of a trombone slide).

The invention also extends to a method of manufacturing a variable phase shifter, the method comprising the steps of:

i) providing first and second coupled signal conductors to provide a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path;

ii) forming a conductive ground plane from a substantially planar sheet of conductive material; and

iii) arranging the ground plane on one side of the signal conductors.

In the preferred method of forming the phase shifter described above, the ground plane is formed from a substantially planar sheet of conductive material. In contrast to a coaxial arrangement (which is conventionally formed by a process of extrusion), the ground plane can be formed from sheet material, eg by stamping or cutting. This makes the manufacturing process cheaper and more simple.

In its finished form the ground plane may not be entirely planar. For instance the sheet may be bent, folded or otherwise formed with walls, grooves, ridges etc. In a preferred embodiment the ground plane is formed with a pair of side walls and a step.

The invention also extends to a method of manufacturing a variable phase shifter, the method comprising the steps of:

i) forming first and second signal conductors from substantially planar conductive sheet material; and

ii) coupling the first and second signal conductors to provide a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path.

The conductors may have sliding conductive contacts whereby the conductors are ohmically coupled, but preferably the second signal conductor is separated from the first signal conductor by a dielectric whereby the first and second signals conductors are capacitively coupled. This acts to minimise intermodulations which may be caused by metal-to-metal contact.

The dielectric may comprise a layer of air but preferably the dielectric comprises a solid or liquid dielectric material.

The solid dielectric may be provided as a separate layer or as a coating (eg a lubricant coating such as polytetrafluoroethane – PTFE, or polyester) on the first and/or the second signal conductor. In the case of the first aspect of the invention the dielectric coating is typically provided on opposed coupling surfaces of the second conductor which couple with the arms of the first conductor.

A problem with PTFE is that it can become abraded after extended use, resulting in direct contact between the signal conductors. This can cause intermodulation.

In accordance with a third aspect of the present invention there is provided a variable phase shifter comprising first and second coupled signal conductors providing a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path, wherein at least one of the signal conductors has a coupling surface which faces the other signal conductor and which is provided with an oxide coating.

The oxide coating acts to prevent direct contact between the relatively moving conductive surfaces – thus preventing intermodulation.

Typically the coating has been formed by a process of anodisation, preferably hard anodisation. Hard anodic oxide coatings have high hardness values and good abrasion characteristics.

Preferably the signal conductor with the oxide coating is formed from Aluminium or an alloy thereof. Aluminium lends itself to easy anodisation.

Typically the anodisation process is performed at a temperature below 5 degrees Celcius.

Typically the anodisation process comprises immersing the conductor in an electrolyte and passing a current through the conductor with a current density greater than 2 amps /dm^2.

Typically the oxide layer has a thickness greater than 25 micron.

One of the conductors (preferably the oxide coated conductor) may have a lubricating coating (eg PTFE) formed on a surface thereof.

The third aspect of the invention also extends to a method of manufacturing a variable phase shifter, the method comprising the steps of:

i) arranging first and second coupled signal conductors to provide a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path; and

ii) forming an oxide coating on a surface of at least one of the signal conductors.

In one preferred embodiment the phase shifter has connection terminals which are soldered directly to coaxial cables. However coaxial cable is expensive and difficult to connect.

In accordance with a fourth aspect of the invention there is provided a variable phase shifter comprising a circuit board having at least two conductive paths formed thereon; a first signal terminal connected to one of the conductive paths; a second signal terminal connected to another one of the conductive paths; and means for providing a variable phase shift between the first and second connection terminals.

The fourth aspect of the invention minimises the amount of coaxial cable required to connect with the phase shifter. Also the terminals can be easily and securely connected to the conductive paths on the circuit board.

Preferably at least two connection apertures are formed in the circuit board, and each signal terminal passes through a respective aperture.

A number of phase shifters may be mounted on the circuit board, and connected by conductive paths. In this case only a single coaxial cable connection is required.

The following comments apply to the phase shifters according to all aspects of the invention.

The variable phase shifter may be incorporated in a power splitter/combiner comprising three or more signal connection terminals, in which the variable phase shifter is coupled between two of the signal terminals.

To minimise signal reflection an impedance matcher may also be coupled between two of the signal terminals.

The phase shifter is preferably employed in a feed network of a phased-array antenna, typically used in a communication network such as a cellular mobile phone network.

Typically the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 400 MHz, and an upper limit equal to or less than 3 GHz. In a preferred case the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 800MHz, and an upper limit equal to or less than 2.5 GHz.

Brief Description of the Drawings

A number of embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic perspective view of a variable phase shifter;

Figure 2 is a plan view of a twin variable phase shifter with all hidden parts shown and the coaxial cables omitted;

Figure 3 is a cross section along line AA in figure 2;

Figure 4 is a cross section along line BB in figure 2;

Figure 5 is a side view of the phase shifter viewed from the left of figure 2;

Figure 6 is plan view of a double phase shifter with all hidden parts shown and the coaxial cables omitted;

Figure 7 is a perspective view of the upper side of a twin variable phase shifter test assembly with the slider in its fully retracted position;

Figure 8 is a side view taken from the left of Figure 7 with all vertical dimensions expanded by 100%;

Figure 8a is a cross-section taken transverse to the direction of signal propagation through one of the support ribs;

Figure 9 is a perspective view of the lower side of the assembly;

Figure 10 is an enlarged perspective view of part of the lower side of the assembly showing a cable connector;

Figure 10a is a cross-section through the connector of Figure 10 showing a connection with a coaxial cable;

Figure 11 is a perspective view of the underside of the assembly with the certain parts removed, and with the slider in its fully extended position;

Figure 12 is an end view taken from the left of Figure 7;

Figure 13 is an enlarged perspective view of part of the assembly;

Figure 14 is an end view of part of the assembly taken from the right of Figure 7;

Figure 15 is a circuit diagram of a dual polarised phased antenna array; and

Figure 16 is a side view of the antenna array of figure 15.

Detailed description of preferred Embodiments

Referring to Figure 1, a variable phase shifter comprises a sheet metal casing 1 which provides a ground plane and is connected to the electrically earthed outer conductors of coaxial cables 2-4. The casing 1 has a planar base shown in figure 1 and also a planar lid (not shown). A variable delay output signal conductor 5 comprises a pair of strips 6,7 of electrically conductive material (such as copper or brass) connected by an end wall 8. Inner conductor 9 of coaxial cable 2 is connected to the end wall 8. An input signal conductor 10 comprises a pair of strips 11,12 of copper or brass connected by an end wall 13. Inner conductor 14 of coaxial cable 3 is connected to the end wall 13. Lower electrode strip 12 has an arm 23 which provides a fixed delay output terminal and is connected to inner conductor 15 of a third coaxial cable 4. Hence an input signal on conductor 14 is split at the end wall 13 and passes along the strips 11,12 which are electrically

parallel (ie electrically connected so as to join with the conductor 14 at a common junction).

A U-shaped slider 16 provides a signal conductor of variable length. The slider 16 has an output arm 17 sandwiched between the strips 6,7 and an input arm 18 sandwiched between the strips 11,12. The upper and lower faces of the copper or brass slider 16 are coated with a low friction dielectric material such as polyester or Teflon™ (PTFE). The slider 16 couples capacitively with the signal conductors 5,10 and by sliding in and out (as indicated at 22) varies the physical length of the transmission path (ie. varies the length of conductor between the cables 3,4 and the cable 2).

The capacitive coupling between the slider 16 and the signal conductors 5,10 is strong enough to provide a wide frequency band pass connection over its full adjustment range.

An input signal 19 on coaxial cable 3 is split and output as a fixed delay output signal 20 on coaxial cable 4 and a variable delay output signal 21 on coaxial cable 2. By adjusting the slider electrode 16 the phase shift of output signal 21 with respect to input signal 19 and fixed delay output signal 20 can be continuously varied.

A twin variable phase shifter package incorporating two phase shifters of the type shown in figure 1 is shown in detail in figures 2-5. The signal conductors are housed in a brass or copper casing comprising a substantially planar base 30, an end wall 35, a pair of side walls 36,37, and a lid 31. The lid 31 has a substantially planar lower portion 32, substantially planar upper portion 33 and a step 34. The lid 31 also has six projecting ears 120, 121, 123-126 which are soldered into recesses in the walls 35-37 to provide a secure electrical connection between the base 30 and lid 31.

Referring to figure 2, the housing 30-37 contains a pair of variable phase shifters 38,39. The phase shifters 38,39 are identical and only the phase shifter 38 will be described in detail below.

The phase shifter 38 comprises an input signal conductor 40, output signal conductor 41 and slider 42. The output signal conductor 41 shown in figure 3 comprises a lower brass or copper strip 48 folded at one end to form an end wall 49 (shown in the detailed view of figure 3). An upper brass or copper strip 47 is soldered to the end wall 49 to lie parallel with the lower strip 48. The input signal conductor shown in figure 4 comprises a pair of parallel brass or copper strips 44,45 and an end wall 46 (figure 2). The U-shaped slider 42 has an input arm 43 sandwiched between the strips 44, 45 and an output arm 50 sandwiched between the strips 47, 48. As shown in the detailed view of figure 4, the upper and lower faces of the slider electrode 42 are coated with PTFE layers 51,52.

The input and output conductors 40,41 are supported by a pair of support assemblies 53,54 shown in Figure 3. The assemblies 53,54 are identical in construction and one of the assemblies 54 is shown in figure 4. The assembly 54 comprises a pair of plastic insulating ribs 55,56 which extend between the side walls 36,37 and are bolted to the base 30 and lid 31. The rib 55 has four recesses which receive the phase shifter conductors. The low friction properties of the PTFE layers 51,52 ensure that the slider 42 can be moved easily and reduces abrasion and intermodulation.

The ribs 55,56 are as narrow as possible to minimise their effect on the wave impedance of the transmission line. In an alternative arrangement the ribs 55,56 may be profiled as indicated by dotted line 54' in figure 2 to make them even narrower. If the ribs cause a step in the wave impedance then

this can be minimised by forming holes (not shown) in the lid 31 and/or base 30 at the points where the ribs lie over the signal conductors.

The pair of sliders are connected to a common insulating drive member 60 which is supported by a pair of sliding bearings 61,62.

In use, six coaxial cables 110-115 (figure 5) are connected to the phase shifter as shown in figure 3 with reference to an input cable 111. Outer conductor 63 of cable 111 is inserted into a hole 66 in the end wall 35 so that the end of the conductor 63 lies flush with the inner surface of the wall 35. The outer conductor is secured to the end wall 35 by solder 64. Inner conductor 65 passes through a hole (not labelled) in the end wall 49, and is secured by solder 67. The end wall 49 is spaced from the casing by an insulating washer 68.

Referring to figure 2, the input signal conductors 40,72 each have a widened portion with a greater width 101 which lowers the impedance of this portion with respect to the slider, output signal conductor and fixed delay output terminal. The widened portion also has a length of one quarter wavelength. This provides impedance matching to minimise reflection of the input signal at the point where the transmission path splits at the fixed delay output terminal.

As can been seen in figure 3, the distance 150 between the upper portion 33 of the lid and the upper strip 47 is approximately equal to the distance 151 between the lower portion 32 of the lid and the slider 42. As a result the wave impedance of the slider 42 is approximately equal to the wave impedance of the signal conductors 40,41. Instead of forming the step 34 by deformation, the step 34 may be formed by adding a sheet of conductor to the underside of the lid 31.

A double variable phase shifter is shown in figure 6. The phase shifter is similar to the twin phase shifter of figures 2-5, the main difference being that the conductor 41 is connected to the conductor 69 of the second phase shifter 39. This produces a double phase shift between input signal 70 and output signal 71. The conductor 72 has a narrow profile (similar to output conductor 41) and there is only a single fixed delay output terminal arm 23.

A twin phase shifter test assembly is shown in Figures 7-14. The two phase shifters 200,201 in the assembly are identical so only the phase shifter 200 will be described below. The signal conductors are mounted on a substantially planar aluminium sheet 202. The sheet 202 provides a first ground plane (analagous to the base 30 in the embodiments of Figures 2-6). However no opposite ground plane is provided with the embodiment of Figures 7-14. Instead, stray lines of flux are collected by a bent brass ground strip having a substantially planar lower portion 203, substantially planar upper portion 204 and an angled step 205. We have found that the relatively narrow width of the strip 204 (compared with the width of the lid 31 in the embodiment of Figures 2-6) does not appreciably degrade the performance of the phase shifter. In fact the strip 204 can be narrowed further and still function as an effective matching shield.

A printed circuit board (PCB) 208 is attached to the opposite major face of the sheet 202 by double-sided adhesive tape (not shown). The PCB 208 comprises an insulating board 300 (shown in the cross-section of figure 10a) with a layer of copper 301 covering one surface and a number of copper lines 210,211 etc formed on its other surface (see Figure 9).

An input leg of the phase shifter is formed by an upper strip 214 and a lower parallel strip 206. The two legs are identical and only the input leg will be

described below. An output leg of the phase shifter is formed by an upper strip 228 and a lower strip 229. The upper strips 214, 228 and ground strips 204 etc. are omitted from Figure 11 to show the lower strips.

The lower brass or copper strip 206 is folded down at one end as shown in figure 8 and has a connection terminal 207 which passes through a hole 351 in the PCB 208 (shown clearly in Figure 13). An upper brass or copper strip 214 is also folded down at one end as shown in Figure 13 and has a connection terminal 215 which passes through the hole 351. The copper layer 301 on the PCB is etched away to form a window 209 surrounding the hole 351 as shown in Figure 13 to ensure that the conductors 206,214 are not electrically earthed. The other surface of the PCB 208 (shown in Figure 9) is printed with copper strips 210,211 with widened end connection regions 212,213 surrounding the terminals 215,207. The terminals 215,207 pass through the PCB 208 as shown in Figure 8. In a subsequent processing step the tabs 215,207 are soldered to the copper connection region 212 to ensure a good connection.

The brass strip 204 (Figures 8,13) is bent at one end and has a terminal 250 which passes through a hole 252 in the PCB 208 as shown in Figure 13. In a subsequent processing step the tab 250 is soldered against the copper layer 301 on the PCB so as to provide a secure ground connection.

A set of metal clips 216,217 etc are connected, when in use, with coaxial cables. The coaxial cables are not shown in Figure 9 but a single illustrative cable connection is shown in the detailed view of Figure 10a. The clip 216 shown in Figures 7 and 10 has a pair of lugs 218,219 which secure the clip against the copper layer 301 on the surface of the PCB. The lugs 218,219 are soldered in a subsequent processing step to ensure a secure connection. The clip 216 also has four arms 220-223 (shown in Figure 10) which pass

through a hole 224 in the PCB 208. The coaxial cable shown in Figure 10a has an outer conductor 225 which engages the arms 220-223 and an inner conductor 226 which engages the copper line 210. In a subsequent processing step the arms 220-223 are bent inwards and soldered to securely grip the outer conductor, and the inner conductor 226 is soldered to the copper strip 210. The connection of figure 10a is physically robust. Also the width of the critical gap 227 between the end of the line 210 and the hole 224 can be accurately controlled.

A U-shaped slider 230 (shown best in Figure 11) has a first arm 231 sandwiched between the strips 206,214 and a second arm 232 sandwiched between the strips 228,229. The slider 230 is connected to a common insulating drive member 238 which is supported by three sliding bearings 239-241. The drive member 238 is formed in a single piece by injection moulding with a central layer 242, upper and lower strengthening layers 243,244 and bosses 236,237 which are received in holes (not labelled) in the slider 230. The bosses 236,237 are flattened against the slider in a subsequent processing step to secure the slider to the drive member 238.

The signal conductors are supported by a pair of supports 233,234. The supports 233,234 are identical in construction and only one will be described below. The support 233 is formed as a single piece of insulating plastic with rectangular holes receiving the signal conductors and snap-fitting clips 234,235 for securing the upper ground conductor strip 204 (as shown in Figure 7). The support 233 is secured to the rest of the assembly by means of lugs 251-253 which pass through holes (not labelled) in the sheet 202 and PCB 208 and snap fit against the opposite side of the PCB 208 shown in Figure 9.

In use, 50 ohm coaxial cables are connected to the clips 216,217. The copper strips 210,211 and phase shifter signal conductors are each dimensioned so as to present a wave impedance of approximately 50 ohm and thus minimise signal reflection.

As in the embodiments of Figures 2-6, the wave impedance of the slider 230 is controlled by the provision of a step 205 in the ground strips.

The slider 230 is manufactured by the process described below.

Slider Manufacturing Process

BATH NO:	DESCRIPTION:	CHEMICAL
1	Preclean	A1 Probright™
2	Preclean Rinse	Overflowing H_20
3	Caustic Etch	Sodium Hydroxide Solution
4	Caustic Rinse	Overflowing H_20
5	Desmut	Nitric Acid Solution
6	Desmut Rinse	Overflowing H_20
7	Hard Anodising	Sulphuric Acid Solution
8	Hard Anodising Rinse	Overflowing H_20
9	Hot Water Rinse	Hot Overflowing H_20

BATH NO. 1 **PRECLEAN**

CHEMICAL: Al PROBRIGHT™

Al Probright is an alkaline cleaner designed to remove soil and most polishing pastes from aluminium and its alloys.

TANK VOLUME: 14.4 litres

BATH COMPOSITION: 10% Al Probright
90% Deionised H_2O

TEMPERATURE: Ambient

TIME: 3 minutes or more depending on contamination.

BATH NO. 2	**PRECLEAN RINSE**
CHEMICAL: OVERFLOWING H_2O	
TANK VOLUME:	18 litres
CHEMICAL TEST:	1. pH 8-10 2. Keep in specs, by controlling the overflow
BATH NO. 3	**CAUSTIC ETCH**
CHEMICAL:	SODIUM HYDROXIDE Sodium hydroxide is a highly alkaline etch that will produce a fine grain matt finish and will prevent the deposition of insoluble aluminium hydroxide in the etch bath.
TANK VOLUME:	14.4 litres
BATH COMPOSITION:	40 gram/litre sodium hydroxide 14.4 litres deionised H_2O
TEMPERATURE:	Ambient
TIME:	3 minutes
BATH NO. 4	**CAUSTIC RINSE**
CHEMICAL: OVERFLOWING H_2O	
TANK VOLUME:	18 litres
CHEMICAL TEST:	1. pH 10-11 2. Keep in specs by controlling the overflow
BATH NO. 5	**DESMUT**
CHEMICAL: NITRIC ACID	Nitric acid is designed to desmut Aluminium Alloys and brightens surface after alkaline etching.
TANK VOLUME:	14.4 litres
BATH COMPOSITION:	30% nitric acid 70% deionised H_2O

TEMPERATURE:	AMBIENT
TIME:	3 minutes

BATH NO. 6 **DESMUT RINSE**

CHEMICAL: OVERFLOWING H_2O

TANK VOLUME:	18 litres
CHEMICAL TEST:	1. pH 2-3 2. Keep in specs by controlling the overflow.

BATH NO. 7 **HARD ANODISING**

CHEMICAL :	SULPHURIC ACID
TANK VOLUME:	14.4 litres
BATH COMPOSITION:	10% sulphuric acid (98%)
OPERATING PARAMETER:	175-225 gram/litre
TEMPERATURE:	0 degrees C ± 1 degree C
TIME:	60 minutes (thickness is very nearly a function of time)
CURRENT DENSITY:	3 amps/ dm^2 – 5 amps/dm^2
A1 ALLOY GRADE:	5005

BATH NO. 8 **HARD ANODISING RINSE**

CHEMICAL: OVERFLOWING H_2O

TANK VOLUME:	18 litres
PARAMETERS:	pH 2-3
IMMERSION TIME:	2 minutes maximum
BATH CONTROL:	Long immersion times together with a pH greater than 3 can lead to non-uniform colouring. Maintain pH by adding sulphuric acid.

BATH NO. 9 **HOT WATER RINSE**

CHEMICAL: OVERFLOWING WATER

TANK VOLUME:	14.4 litres
TEMPERATURE:	50-60 degrees C
CHEMICAL TEST:	pH 6-7
	Maintain pH specs by adjusting overflow rate.

It will be noted that the process does not include a sealing step. This is excluded to ensure a hard-wearing oxide coating.

The slider is formed from Aluminium alloy which is hard anodised (see BATH NO. 7 described above) to form an oxide layer shown in figure 8a. Figure 8a is a cross-section through part of the support rib 233. Figure 8a is not to scale. The support rib has a hole 310 which is sized to loosely receive the signal conductors. In one example the hole 310 is 2.4mm high and the signal conductors 206,214,231 are 0.7mm thick – giving a total 0.3mm of play. The hole 310 can be accurately positioned and sized so as to accurately control the wave impedance of the conductors.

The slider arm 231 shown in Figure 8a has an Aluminium alloy core 311 surrounded by a 50 micron thick layer of oxide 312, formed during hard-anodisation. The upper and lower faces of the slider are spray-coated with thin PTFE layers 313,314.

In use, the low friction properties of the PTFE reduces abrasion between the moving parts. If the PTFE layers 313,314 wear through, then the oxide layer 312 (which is an electrical insulator) prevents any metal-to-metal contact between the electrodes and thus prevents intermodulation. The oxide layer

312 is also relatively hard-wearing and we have found that the PTFE tends to impregnate cracks in the oxide, and thus improves the wear characteristics.

If necessary the PTFE layers 313,314 can be omitted. The signal conductors 206,214 may also be formed of hard anodised Aluminium alloy with a PTFE coating.

The assembly illustrated in Figures 7-14 is a test assembly for testing the performance of the phase shifter. When installed in a phased array antenna system (as discussed below), a number of phase shifters can be mounted on a single PCB and connected together by conductive lines on the upper surface of the PCB. In this arrangement only a single coaxial connection to the PCB is required.

The phase shifters of figures 2-14 may be used in the circuit arrangement of figure 15. A signal generator 80 generates a signal which is input to a double phase shifter 81 of the type shown in figure 6. The subsidiary output terminal arm 23 of the phase shifter 81 is connected to a phase shifter 82 which is connected in turn to a pair of dual polarised radiators 83,84. The variable delay output of phase shifter 81 is input to a phase shifter 85 which is connected in turn to a pair of dual polarised radiators 86,87. The opposite terminals of the radiators are driven by a complementary set of drive circuitry shown in the upper half of figure 15.

The phase shifters 82,95 may be housed together in a twin phase shifter package. Similarly the phase shifters 85,96 may be housed together in a twin phase shifter package. Alternatively phase shifters 95,96 and 82,85 may be housed together.

Referring to Figure 16, the antennas 83,84,86,87 are arranged vertically and emit phase shifted signals which travel as a common wavefront 97. The wavefront 97 is downtilted by an angle 98 proportional to the relative phase shift of the signals. Thus the angle of downtilt can be adjusted by adjusting the variable phase shifters 81,82,85,95,96,99. Typically this is achieved by connecting the drive member 60 of the four phase-shifter packages to a common drive arm.

Typically the antennas are part of a cellular communication system and transmit in a wavelength range between 800 and 2500 MHz. However it will be appreciated that the phase shifters described may be operated in a variety of wavelength regions by suitable scaling.

It will be seen that the present invention provides a variable phase shifter which is easy to manufacture and has a wide phase shift range. Although the phase shifter has been illustrated in use with a transmitting antenna array, it will be understood that the phase shifter may also be used with a receiving antenna array. In this case, instead of acting as a phase shifter/power splitter it will act as a phase shifter/power combiner.

Although this invention has been described by way of example it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope of the invention as defined in the appended claims.

CLAIMS:

1. A variable phase shifter comprising first and second capacitively coupled signal conductors providing a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path, wherein the first signal conductor comprises a pair of electrically parallel arms, and wherein the second signal conductor is arranged between the arms of the first signal conductor.

2. A variable phase shifter according to claim 1 further comprising support means arranged on opposite sides of the first signal conductor so as to maintain a maximum spacing between the arms of the first signal conductor.

3. A variable phase shifter comprising first and second coupled signal conductors providing a transmission path through the phase shifter, wherein the signal conductors are relatively movable to vary the physical length of the transmission path; and wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

4. A variable shifter according to claim 3 and claim 1 or 2.

5. A variable phase shifter according to any one of the preceding claims, further comprising a conductive ground plane arranged on at least one side of the signal conductors.

6. A variable phase shifter according to claim 5 further comprising a second ground plane arranged on an opposite side of the signal conductors.

7. A variable phase shifter according to claim 5 or 6 wherein one or both of the ground planes has a first portion adjacent the first conductor, a second portion adjacent the second conductor, and a step between the first and second portions.

8. A variable phase shifter according to any of claims 5 to 7 wherein the signal conductors each have substantially planar surfaces which face the or each ground plane.

9. A variable phase shifter according to any one of claims 5 to 8 wherein the or each ground plane has one or more substantially planar surface portions facing the first and second signal conductors.

10. A variable phase shifter according to any one of claims 5 to 9 wherein the ground plane and the first and second signal conductors each have a respective width transverse to a direction of signal propagation, and wherein the width of the ground plane is more than three times greater than the width of each of the signal conductors.

11. A variable phase shifter according to any one of claims 5 to 10 wherein the ground plane is formed from a substantially planar sheet of conductive material.

12. A variable phase shifter comprising first and second coupled signal conductors providing a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path, wherein at least one of the signal conductors has a coupling surface which faces the other signal conductor and which is provided with an oxide coating.

13. A variable phase shifter according to claim 12 wherein the coating has been formed by a process of anodisation.

14. A variable phase shifter according to claim 13 wherein the coating has been formed by a process of hard anodisation.

15. A variable phase shifter according to any one of claims 12 to 14 wherein the signal conductor with the oxide coating is formed from Aluminium or an alloy thereof.

16. A variable phase shifter according to any one of claims 12 to 15 wherein at least one of the signal conductors has a lubricating coating formed on a surface thereof.

17. A variable phase shifter according to claim 16 wherein the lubricating coating is formed on top of the oxide coating.

18. A variable phase shifter according to any one of claims 12 to 17 wherein the first and second signal conductors have opposed substantially planar coupling surfaces.

19. A variable phase shifter according to claim 1 wherein the arms of the first signal conductor each have substantially planar coupling surfaces which are arranged on opposite sides of the second signal conductor and which lie substantially parallel with each other.

20. A variable phase shifter according to any one of the preceding claims further comprising a third signal conductor, wherein the second signal conductor has a first arm coupled to the first signal conductor and a second arm coupled to the third signal conductor whereby the second signal

conductor provides a transmission path between the first and third signal conductors, and wherein the second signal conductor and the first and third signal conductors are relatively moveable to vary the physical length of the transmission path.

21. A variable phase shifter according to claim 20 wherein the first and second arms of the third signal conductor extend in substantially parallel directions.

22. A variable phase shifter according to any one of the preceding claims wherein the second signal conductor is separated from the first signal conductor by a dielectric.

23. A variable phase shifter according to claim 22 wherein the dielectric comprises a solid or liquid dielectric material.

24. A variable phase shifter according to claim 23 wherein the dielectric comprises a dielectric coating on the first and/or the second signal conductor.

25. A variable phase shifter according to claim 23 or 24 wherein the dielectric material is in contact with both signal conductors whereby the dielectric material provides a sliding bearing surface when the signal conductors are relatively moved.

26. A variable phase shifter comprising a circuit board having at least two conductive paths formed thereon; a first signal terminal connected to one of the conductive paths; a second signal terminal connected to another one of the conductive paths; and means for providing a variable phase shift between the first and second connection terminals.

27. A phase shifter according to claim 26 further comprising at least two connection apertures formed in the substantially planar surface, wherein each signal terminal passes through a respective aperture.

28. A phase shifter according to claim 26 or 27 further comprising a coaxial cable having an inner conductor and an outer conductor, wherein the inner conductor is connected to one of the conductive paths.

29. A variable phase shifter according to any one of the preceding claims, wherein the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 400 MHz, and an upper limit equal to or less than 3 GHz.

30. A variable phase shifter according to claim 29, wherein the phase shifter is dimensioned to provide a variable phase shift for signals in a wavelength band having a lower limit equal to or greater than 800MHz, and an upper limit equal to or less than 2.5 GHz.

31. A power splitter/combiner comprising three or more signal terminals and a variable phase shifter according to any one of the preceding claims coupled between two of the signal terminals.

32. A power splitter/combiner according to claim 31 further comprising an impedance matcher coupled between two of the signal terminals.

33. A phased array antenna comprising at least two radiating elements; and a feed network for feeding relatively phase-shifted signals to the radiating elements, wherein the feed network comprises one or more variable phase shifters according to any one of claims 1 to 30 and/or a power splitter/combiner according to claim 31 or 32.

34. A cellular telecommunications system comprising a phased array antenna according to claim 33.

35. A method of manufacturing a variable phase shifter, the method comprising the steps of:

i) arranging first and second coupled signal conductors to provide a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path;

ii) forming a conductive ground plane from a substantially planar sheet of conductive material; and

iii) arranging the ground plane on one side of the signal conductors.

36. A method according to claim 35 wherein the step of forming the ground plane includes the step of bending a pair of opposed edges of the sheet to form a pair of side walls.

37. A method according to claim 35 or 36 wherein the step of forming the ground plane includes the step of bending the sheet so as to form a step between a first portion adjacent the first conductor and a second portion adjacent the second conductor.

38. A method according to any one of claims 35 to 37 wherein the step of providing the first and second signal conductors includes the step of forming each of the conductors from a substantially planar sheet of conductive material.

39. A method of manufacturing a variable phase shifter, the method comprising the steps of:

i) forming first and second signal conductors from substantially planar conductive sheet material; and

ii) coupling the first and second signal conductors to provide a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path.

40. A method of manufacturing a variable phase shifter, the method comprising the steps of:

i) arranging first and second coupled signal conductors to provide a transmission path through the phase shifter, the signal conductors being relatively movable to vary the physical length of the transmission path; and

ii) forming an oxide coating on a surface of at least one of the signal conductors.

41. A method according to claim 40 wherein step i) comprises forming the oxide by a process of anodisation.

42. A method according to claim 41 wherein step i) comprises forming the oxide by a process of hard anodisation.

43. A method according to claim 42 wherein the anodisation process is performed at a temperature below 5 degrees Celcius.

44. A method according to any one of claims 41 to 43 wherein the anodisation process comprises immersing the conductor in an electrolyte and passing a current through the conductor with a current density greater than 2 amps /dm^2.

45. A method according to any one of claims 40 to 44 further comprising the step of forming a lubricating coating on a surface of at least one of the signal conductors.

46. A method according to claim 45 wherein the lubricating coating is formed on top of the oxide coating.

47. A variable phase shifter manufactured by the method of any one of claims 35 to 46.

48. A variable phase shifter according to claim 5 further comprising a conductive ground strip arranged on an opposite side of the signal conductors, the ground strip having a width transverse to a direction of signal propagation which is less than the width of the ground plane.

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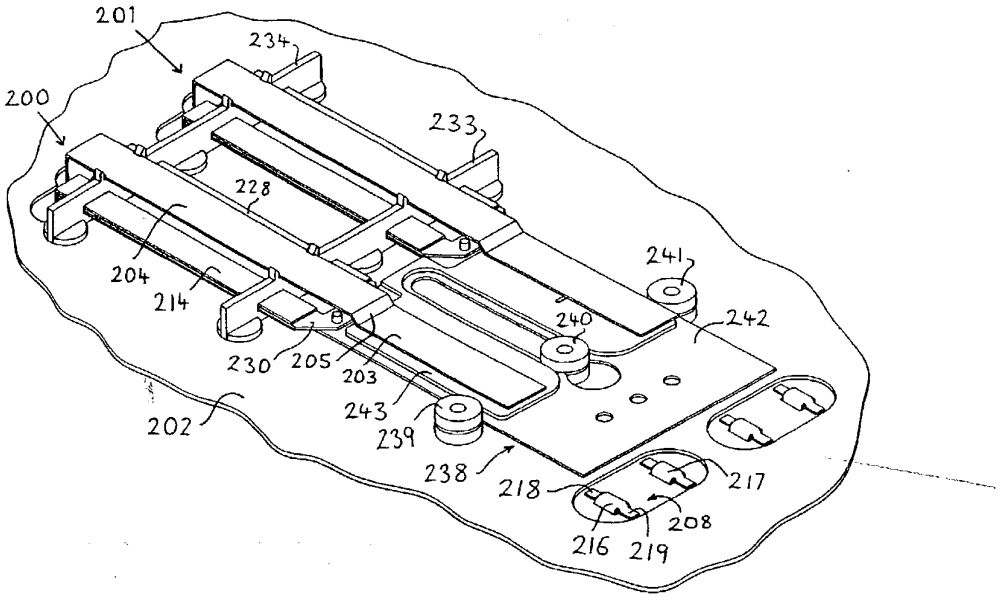
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: VARIABLE PHASE SHIFTER



(57) Abstract: A variable phase shifter comprising first and second coupled signal conductors (6, 7, 17) providing a transmission path through the phase shifter. The signal conductors are relatively movable to vary the physical length of the transmission path. The first signal conductor comprises a pair of electrically parallel arms (6, 7), and the second signal conductor (17) is arranged between the arms of the first signal conductor. A ground plane (1) is arranged on one side of the signal conductors.

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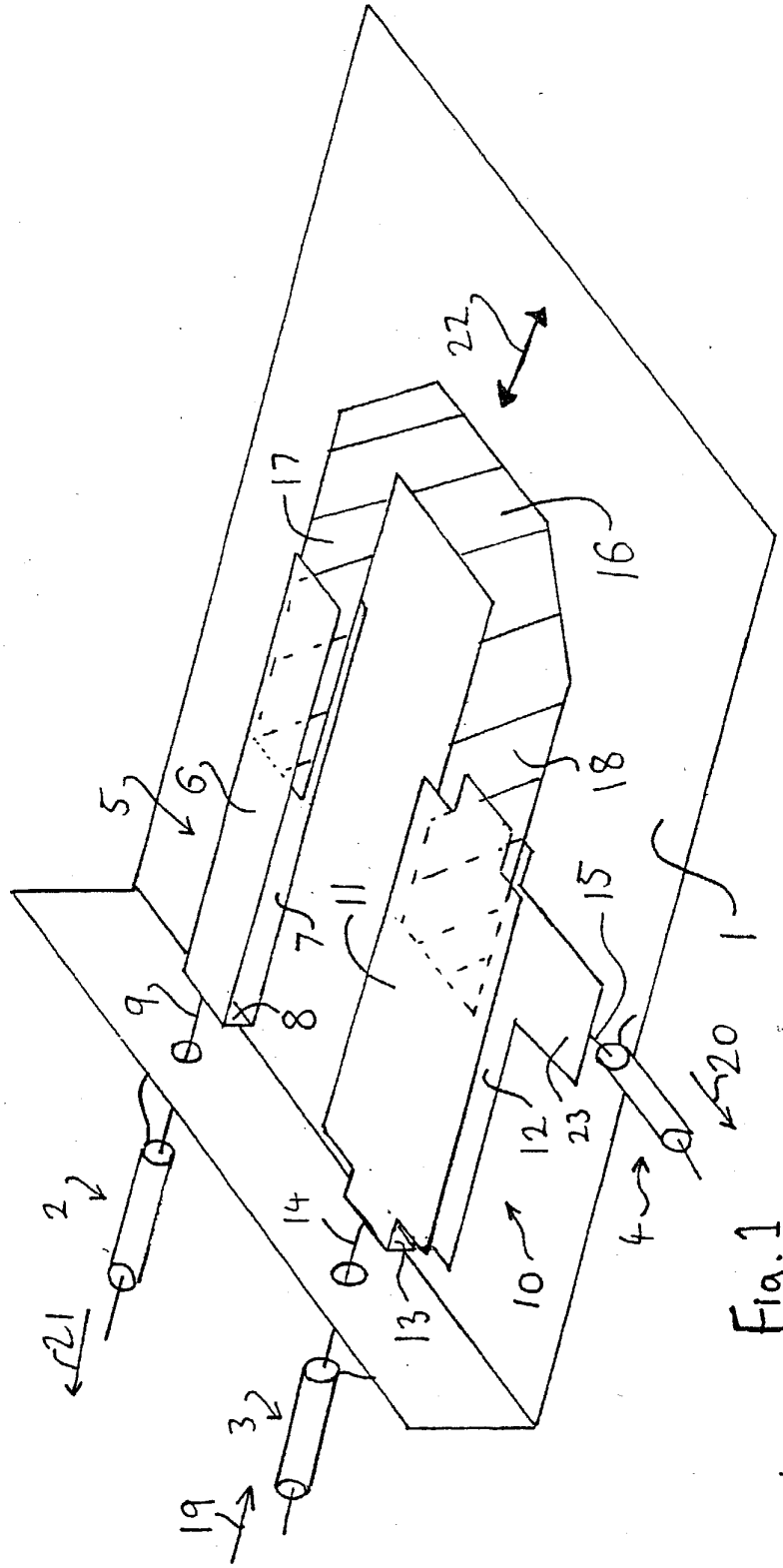

Fig. 1

Inventor: DU TOIT et al.
Docket No.: 8436.88USWO
Title: VARIABLE PHASE SHIFTER
Attorney Name: Brian H. Batzli
Phone No.: 612.336.4755
Sheet 2 of 14

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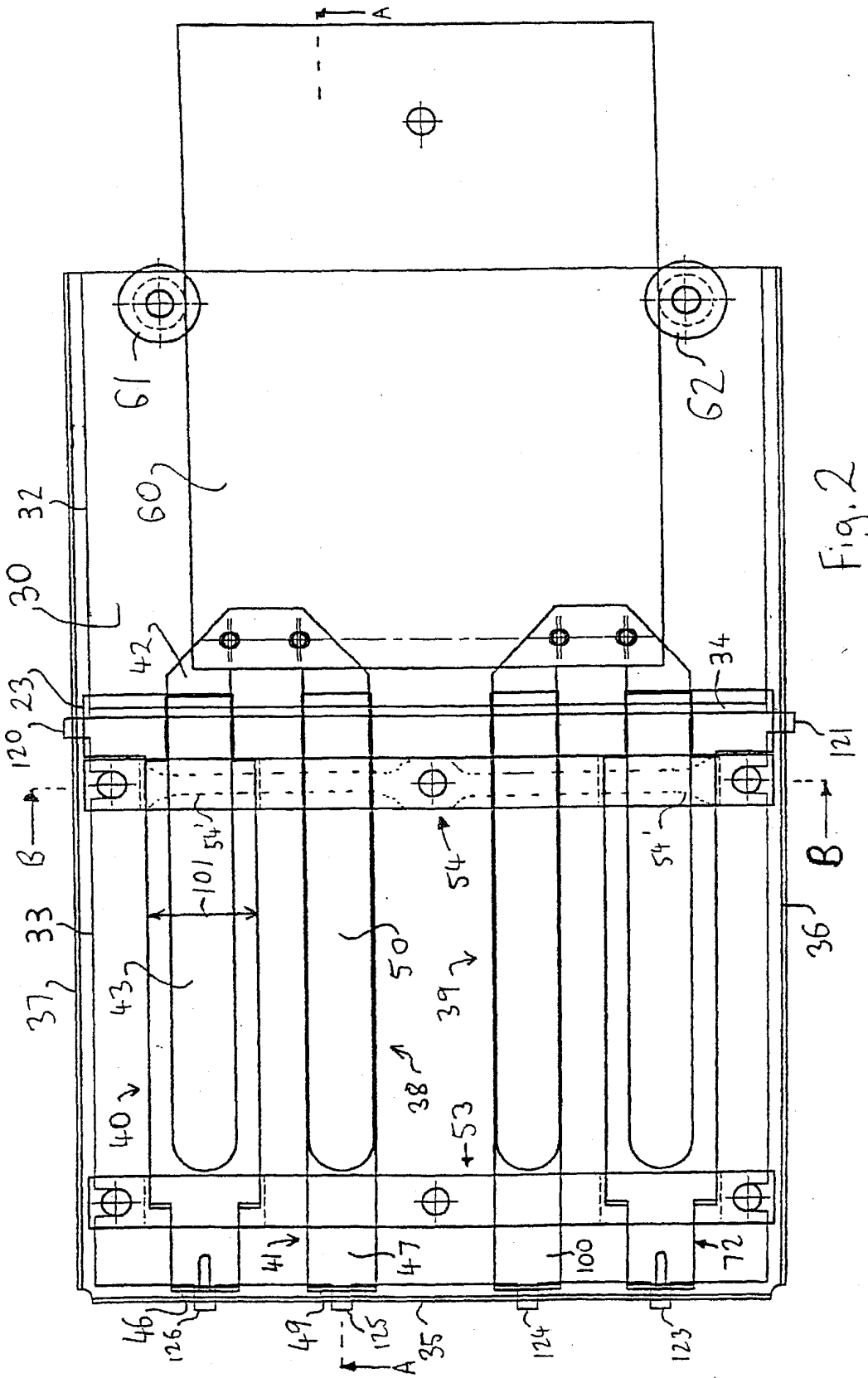

Fig. 2

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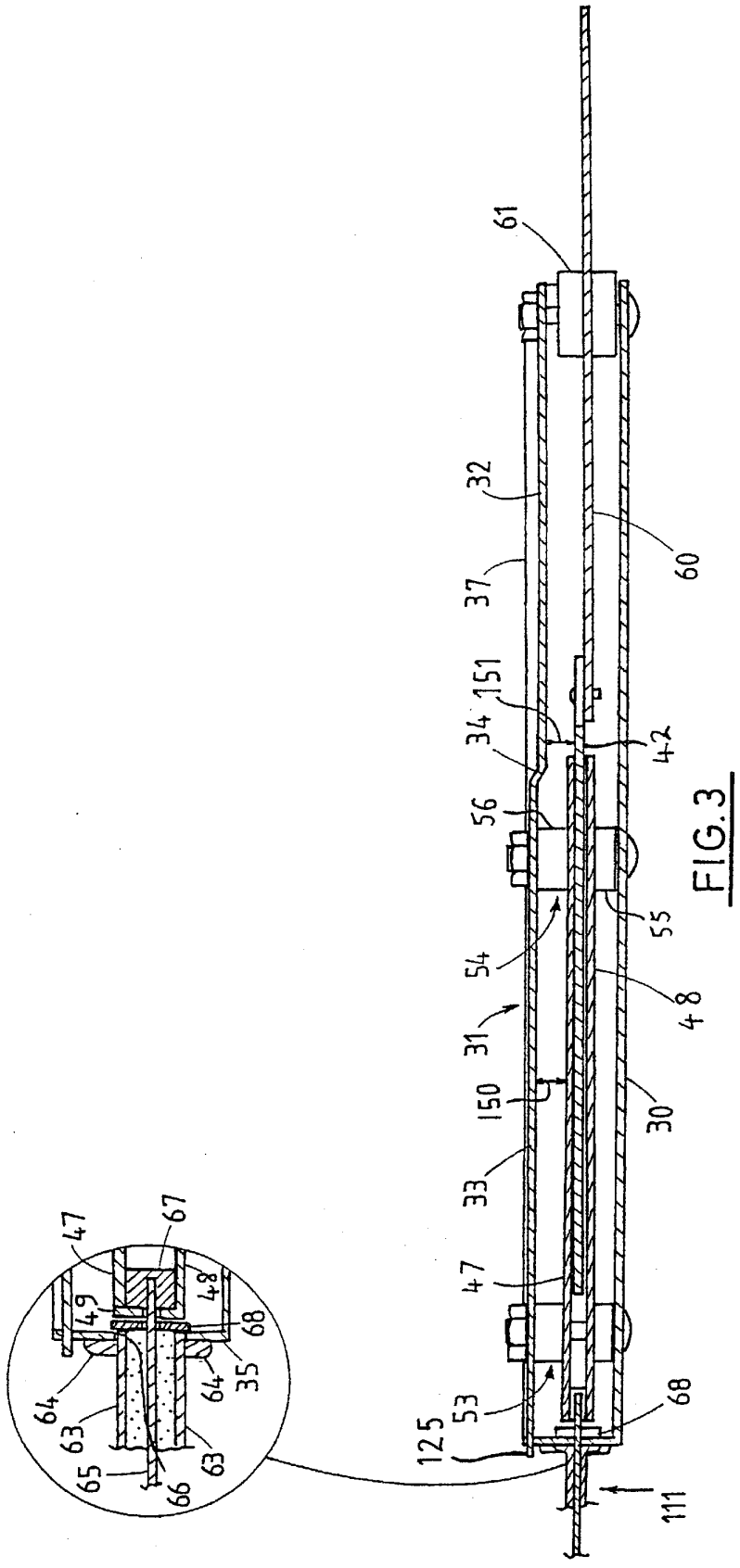

FIG.3

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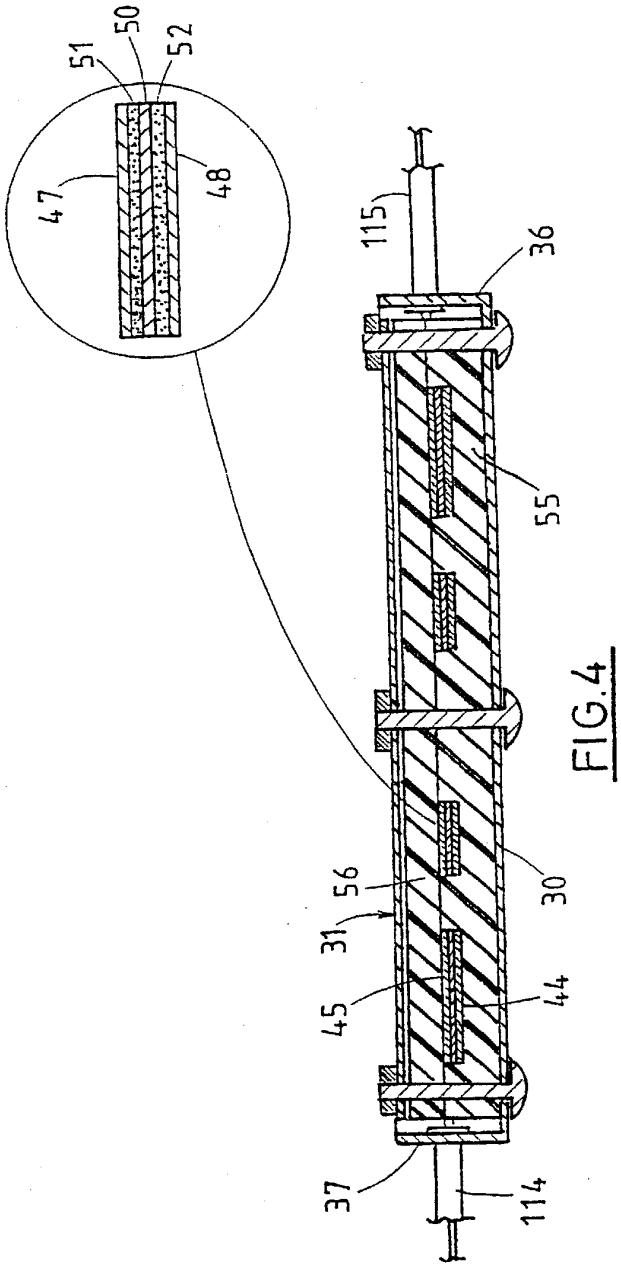

FIG.4

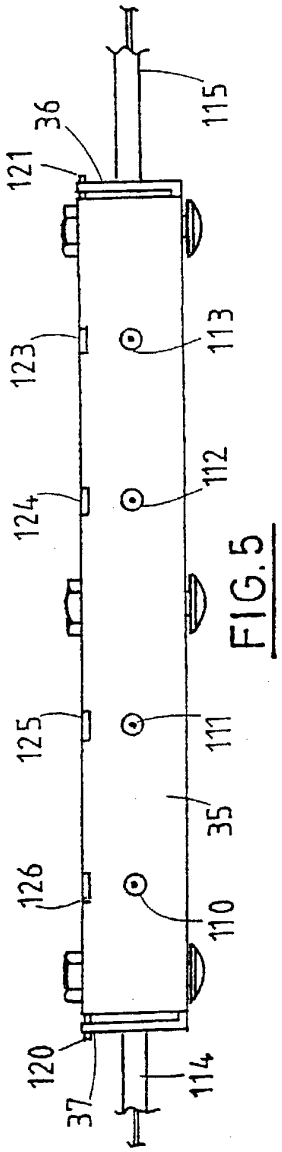

FIG.5

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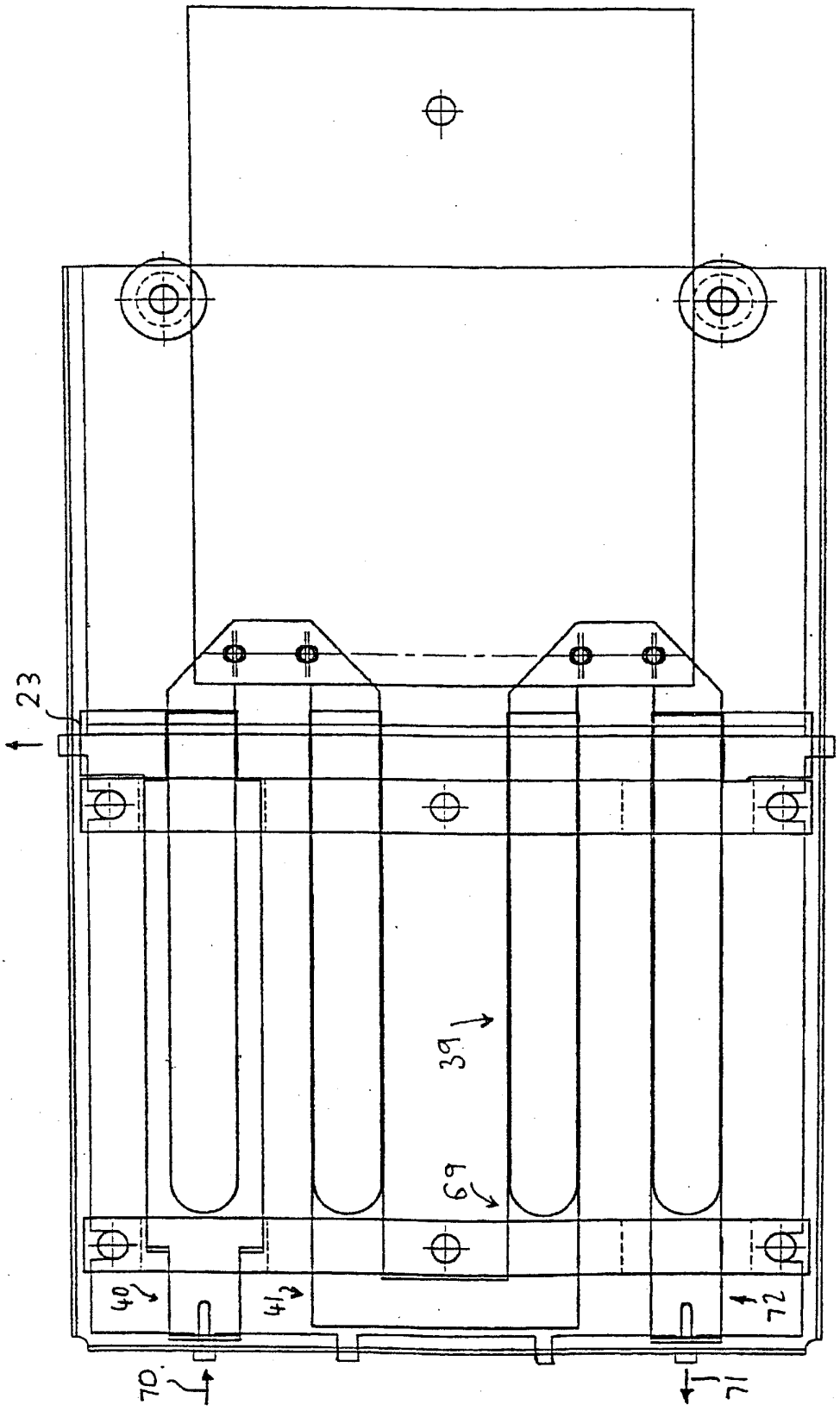

Fig. 6

FIG. 7

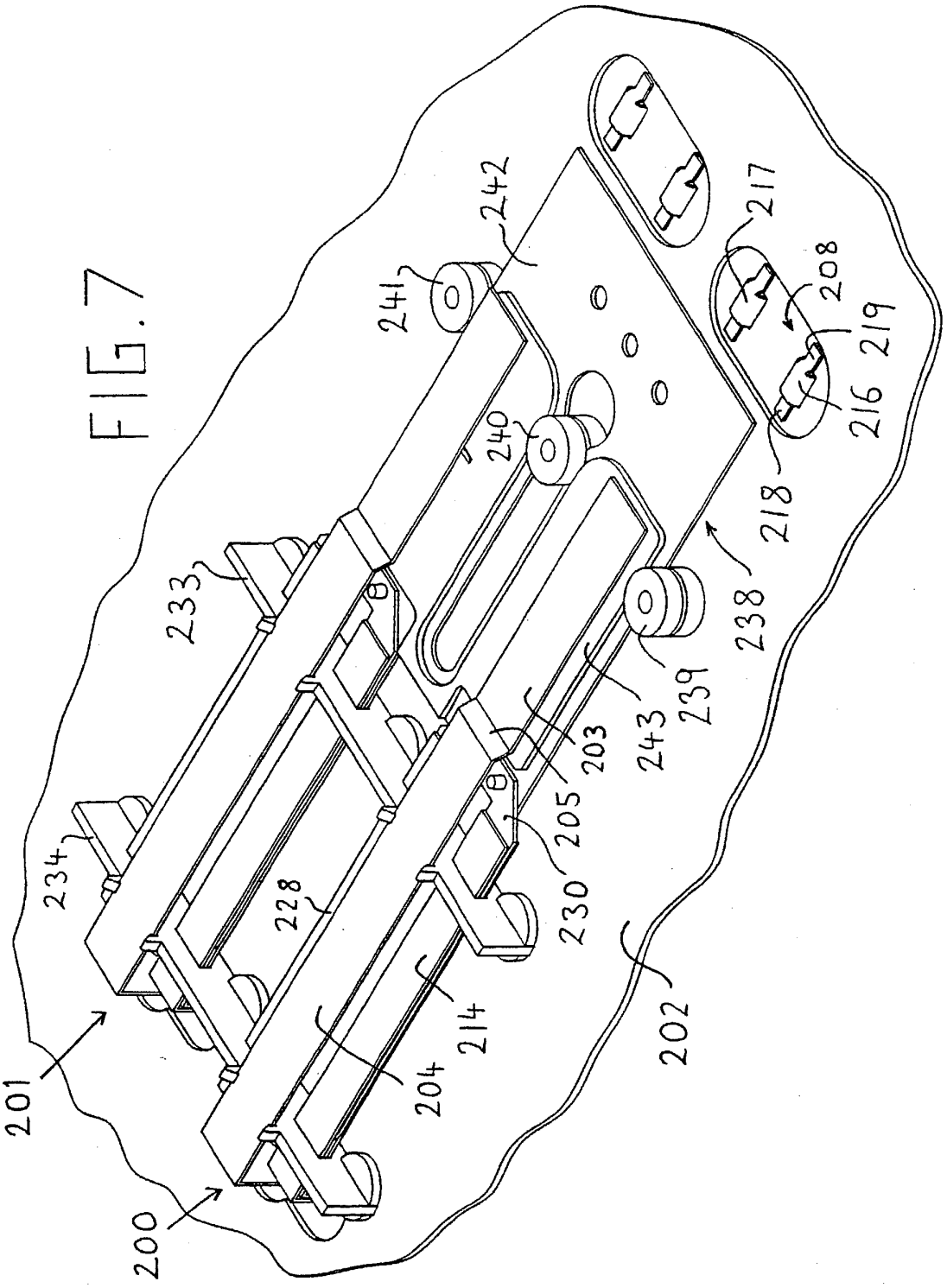
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FIG. 8

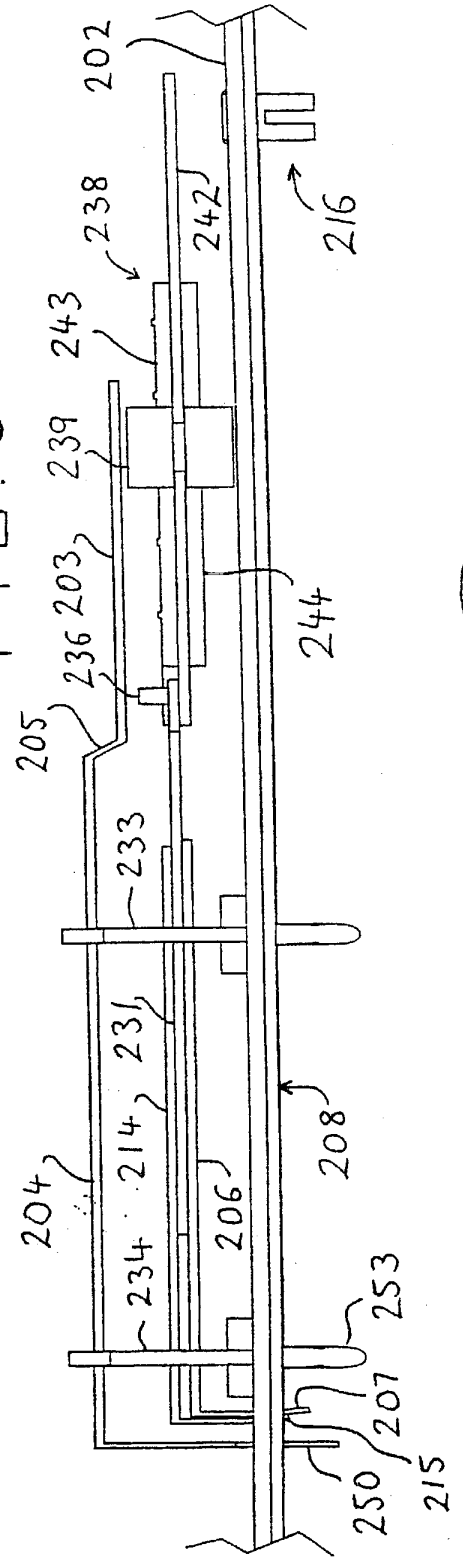
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FIG. 8a

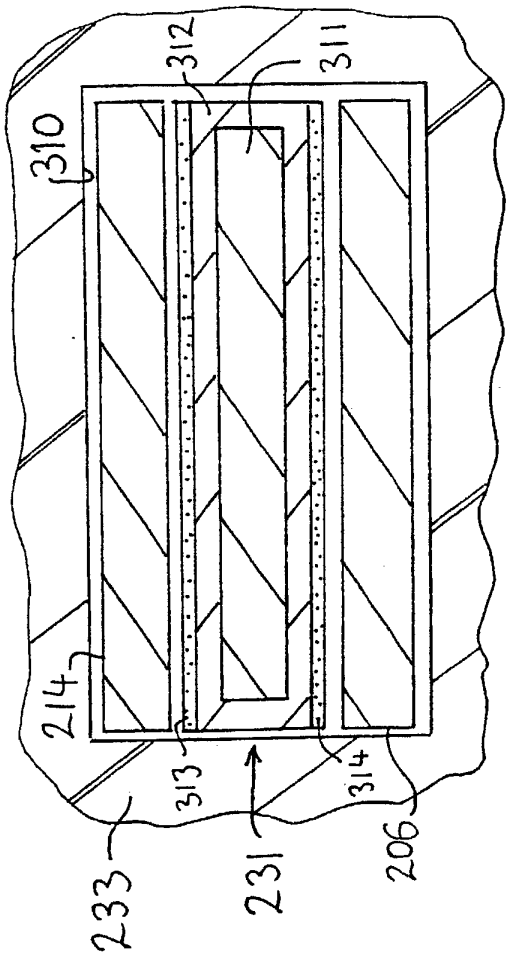
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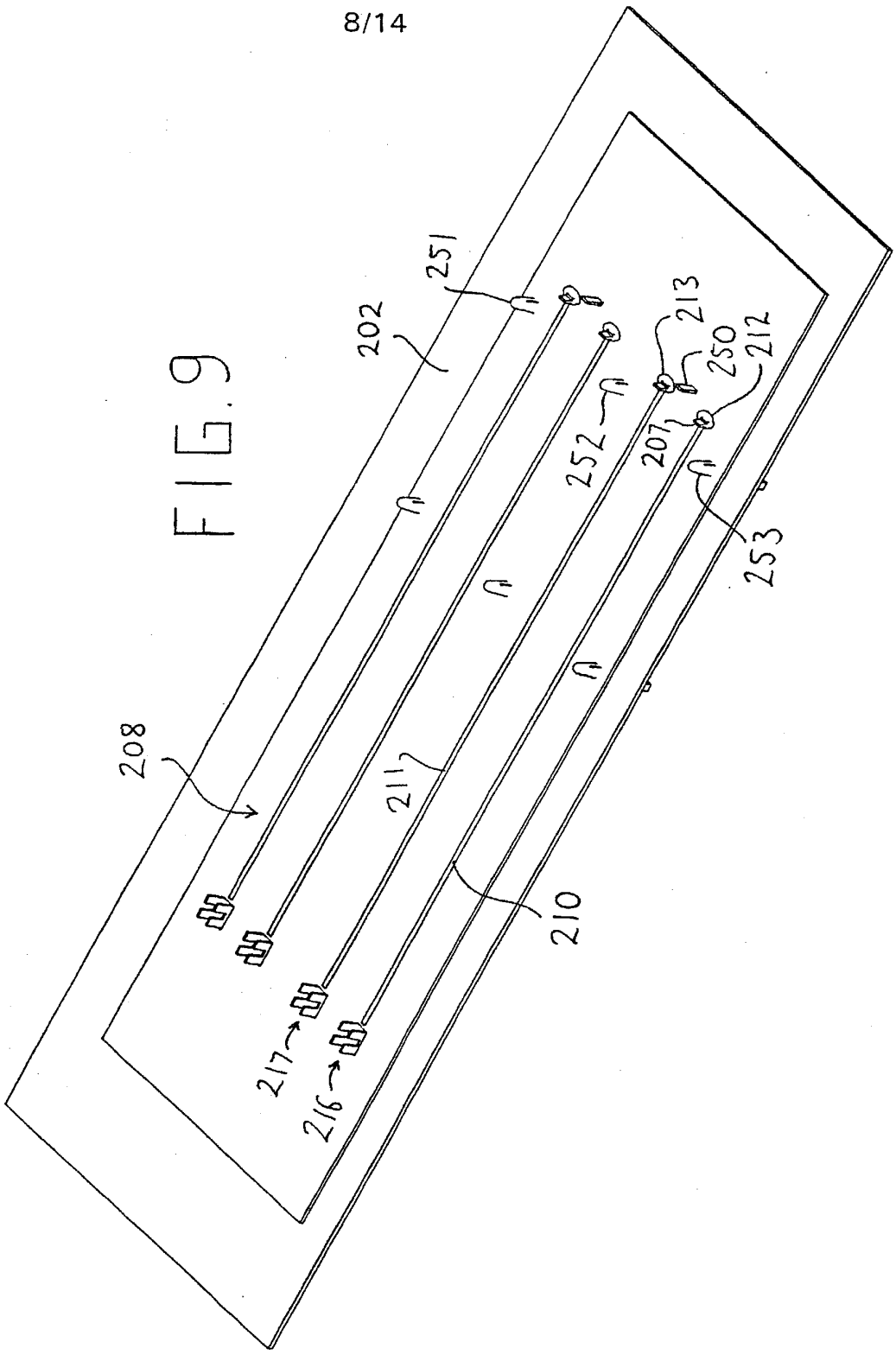
FIG. 9



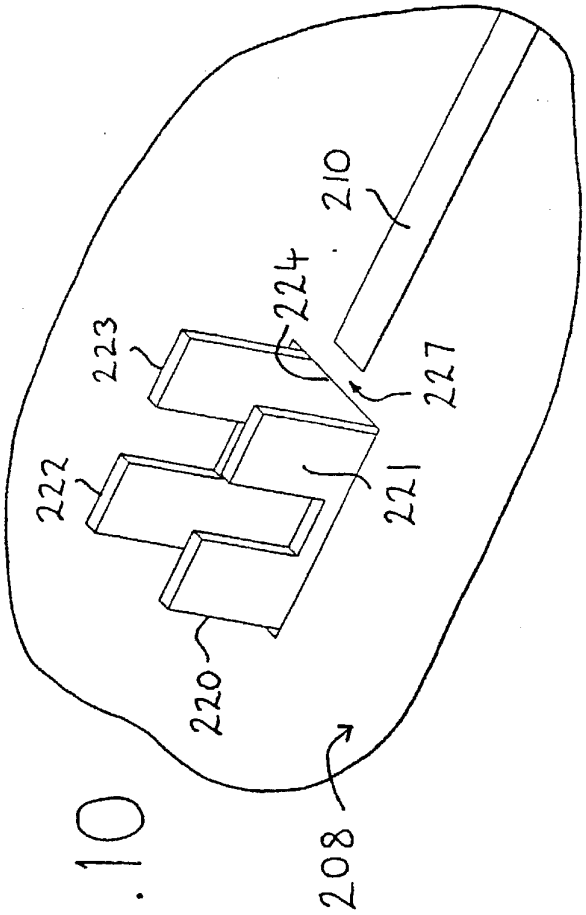


FIG. 10

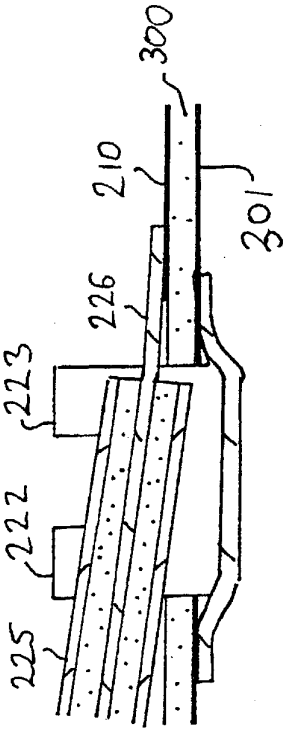


FIG. 10a

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FIG.11

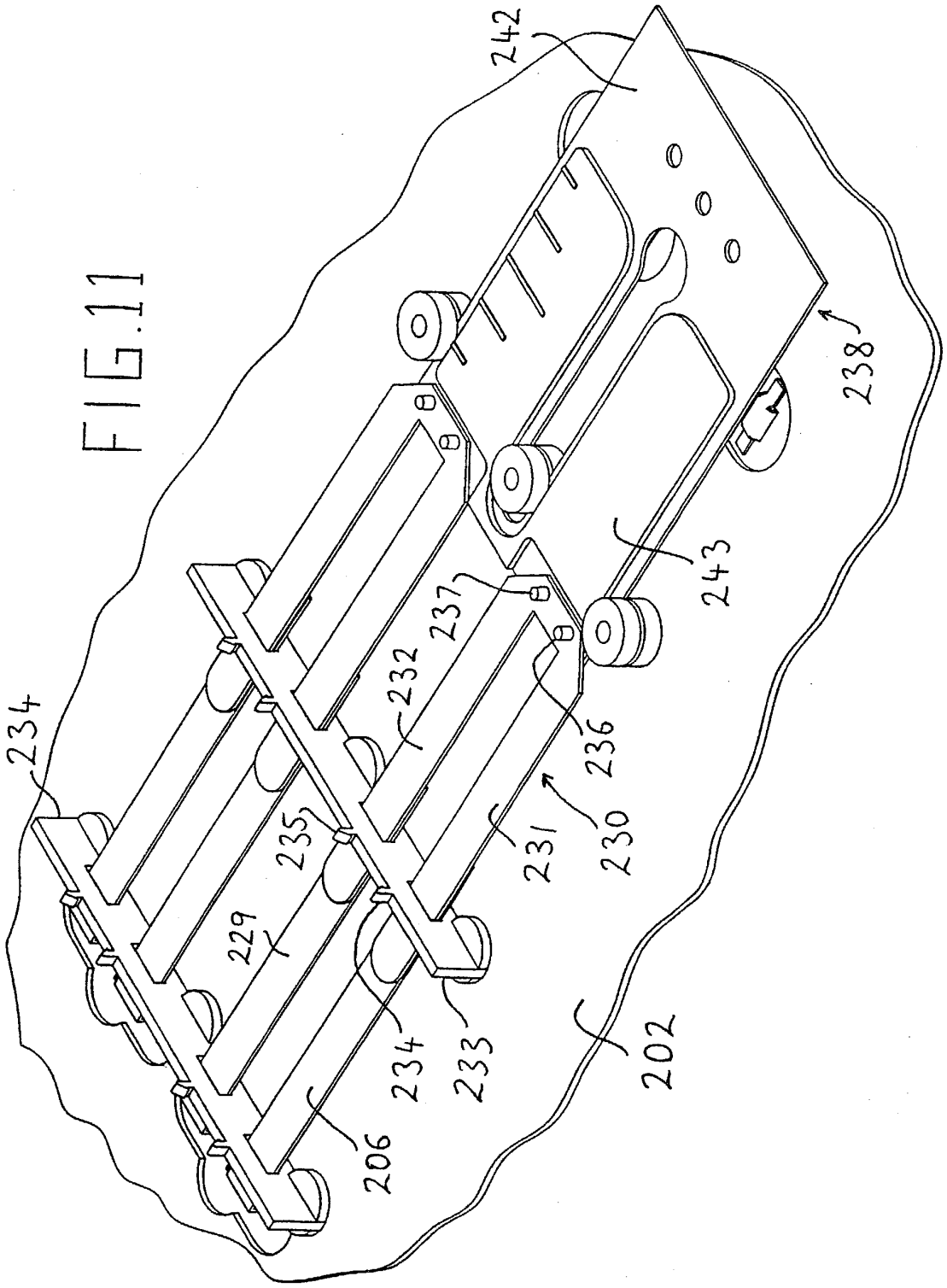
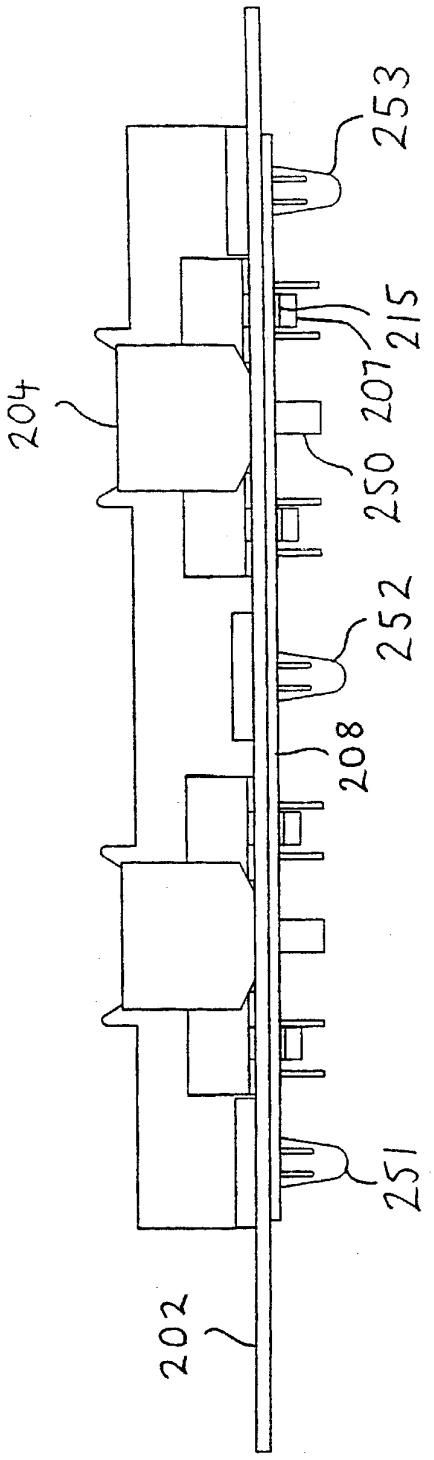


FIG.12



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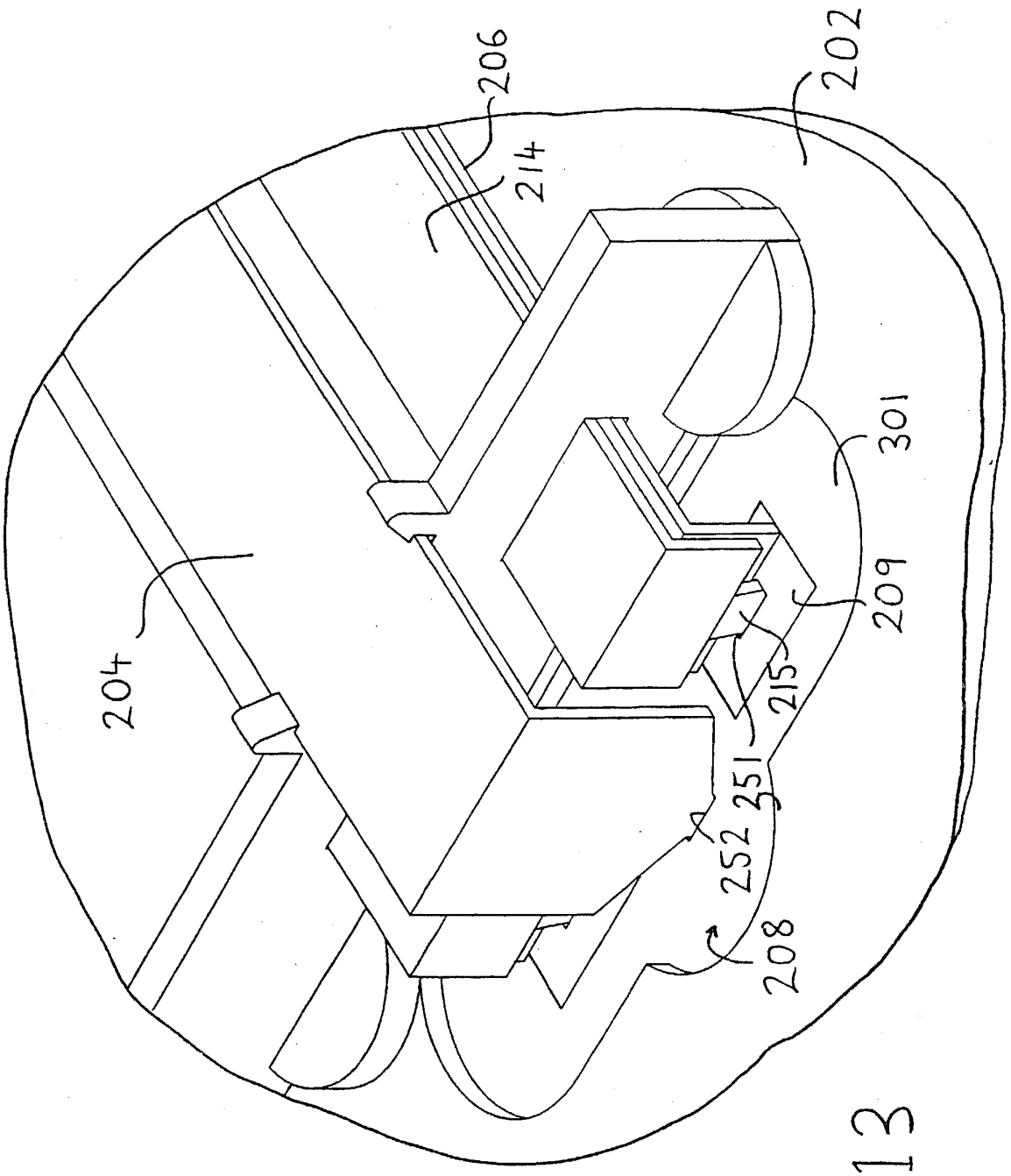

FIG. 13

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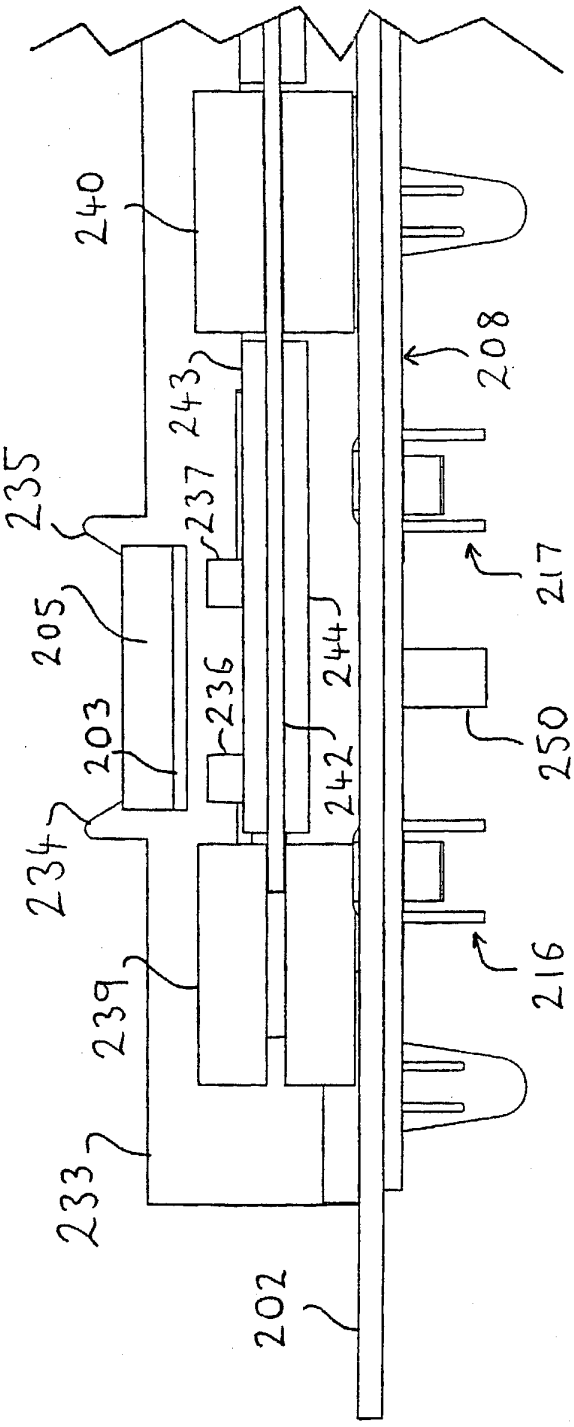
FIG.14



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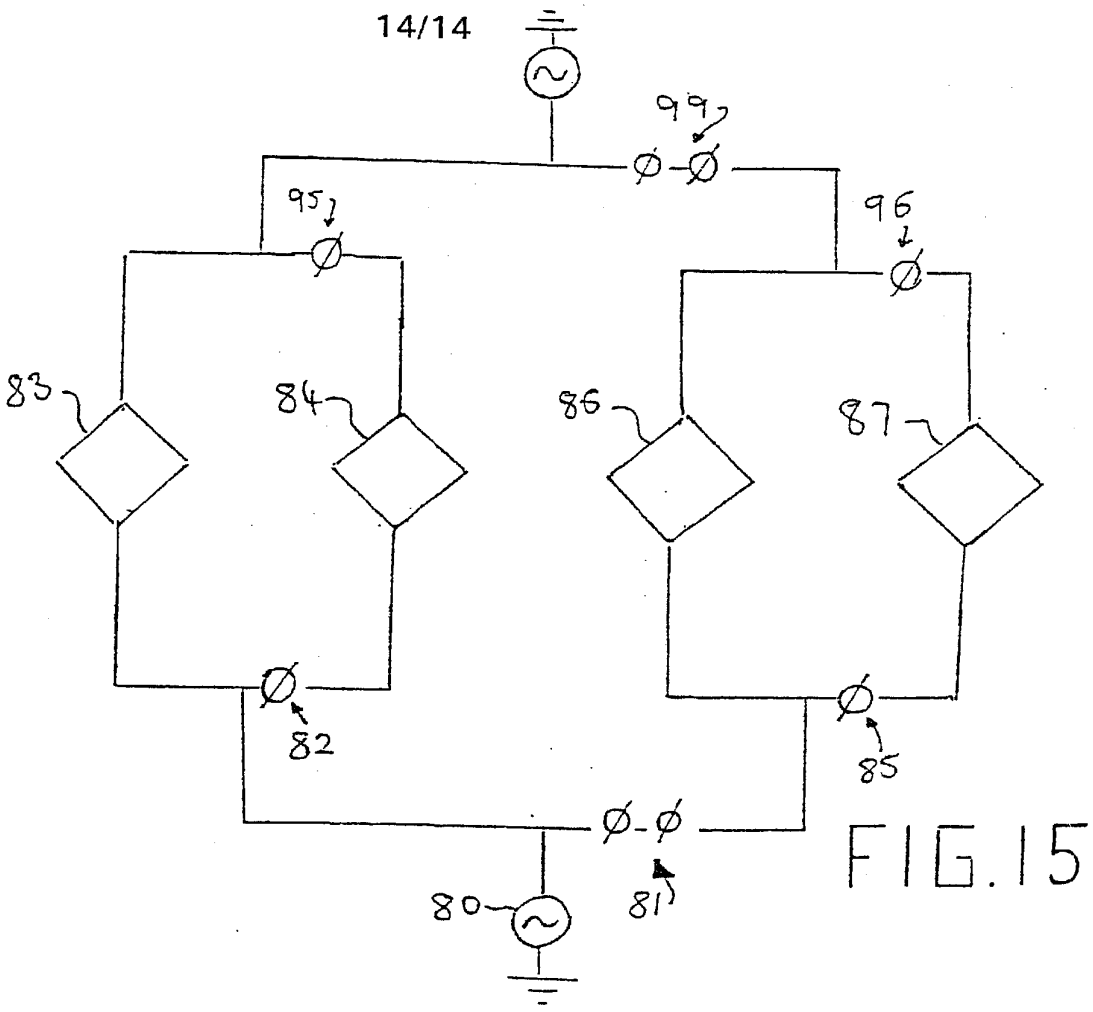

FIG.15

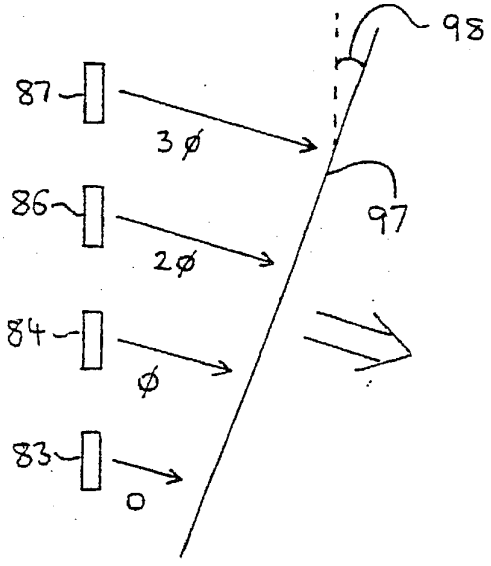

FIG.16

Attorney Docket No. 8436.88USWO

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: VARIABLE PHASE SHIFTER

The specification of which
a. ☐ is attached hereto
b. ☒ was filed on November 20, 2001 as application serial no. 09/979586 and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. PCT/IB00/00739 filed May 22, 2000 and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
New Zealand	335901	May 20, 1999	

ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

I acknowledge the duty to disclose information that is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (reprinted below):

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim

or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

(e) In any continuation-in-part application, the duty under this section includes the duty to disclose to the Office all information known to the person to be material to patentability, as defined in paragraph (b) of this section, which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

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Ali, M. Jeffer	Reg. No. 46,359	Liepa, Mara E.	Reg. No. 40,066
Altera, Allan G.	Reg. No. 40,274	Lindquist, Timothy A.	Reg. No. 40,701
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Batzli, Brian H.	Reg. No. 32,960	Mayfield, Denise L.	Reg. No. 33,732
Beard, John L.	Reg. No. 27,612	McDonald, Daniel W.	Reg. No. 32,044
Berns, John M.	Reg. No. 43,496	McIntyre, Jr., William F.	Reg. No. 44,921
Branch, John W.	Reg. No. 41,633	Mitchem, M. Todd	Reg. No. 40,731
Brown, Jeffrey C.	Reg. No. 41,643	Mueller, Douglas P.	Reg. No. 30,300
Bruess, Steven C.	Reg. No. 34,130	Nelson, Anna M.	Reg. No. 48,935
Byrne, Linda M.	Reg. No. 32,404	Paley, Kenneth B.	Reg. No. 38,989
Campbell, Keith	Reg. No. 46,597	Parsons, Nancy J.	Reg. No. 40,364
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Caspers, Philip P.	Reg. No. 33,227	Phillips, John B.	Reg. No. 37,206
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Epp Ryan, Sandra	Reg. No. 39,667	Schumann, Michael D.	Reg. No. 30,422
Glance, Robert J.	Reg. No. 40,620	Scull, Timothy B.	Reg. No. 42,137
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Gorman, Alan G.	Reg. No. 38,472	Stewart, Alan R.	Reg. No. 47,974
Gould, John D.	Reg. No. 18,223	Stoll-DeBell, Kirstin L.	Reg. No. 43,164
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Hamer, Samuel A.	Reg. No. 46,754	Swenson, Erik G.	Reg. No. 45,147
Hamre, Curtis B.	Reg. No. 29,165	Tellekson, David K.	Reg. No. 32,314
Harrison, Kevin C.	Reg. No. 46,759	Trembath, Jon R.	Reg. No. 38,344
Hertzberg, Brett A.	Reg. No. 42,660	Tunheim, Marcia A.	Reg. No. 42,189
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Holzer, Jr., Richard J.	Reg. No. 42,668	Vandenburgh, J. Derek	Reg. No. 32,179
Hope, Leonard J.	Reg. No. 44,774	Wahl, John R.	Reg. No. 33,044
Jardine, John S.	Reg. No. P-48,835	Weaver, Paul L.	Reg. No. 48,640
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Johnston, Scott W.	Reg. No. 39,721	Whipps, Brian	Reg. No. 43,261
Kadievitch, Natalie D.	Reg. No. 34,196	Whitaker, John E.	Reg. No. 42,222
Kaseburg, Frederick A.	Reg. No. 47,695	Wier, David D.	Reg. No. P-48,229
Kettelberger, Denise	Reg. No. 33,924	Williams, Douglas J.	Reg. No. 27,054
Keys, Jeramie J.	Reg. No. 42,724	Withers, James D.	Reg. No. 40,376
Knearl, Homer L.	Reg. No. 21,197	Witt, Jonelle	Reg. No. 41,980
Kowalchyk, Alan W.	Reg. No. 31,535	Wong, Thomas S.	Reg. No. 48,577
Kowalchyk, Katherine M.	Reg. No. 36,848	Wu, Tong	Reg. No. 43,361
Lacy, Paul E.	Reg. No. 38,946	Young, Thomas	Reg. No. 25,796
Larson, James A.	Reg. No. 40,443	Zeuli, Anthony R.	Reg. No. 45,255

hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization /ho/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be epresented unless/until I instruct Merchant & Gould P.C. to the contrary.

understand that the execution of this document, and the grant of a power of attorney, does not in itself establish an attorney-client elationship between the undersigned and the law firm Merchant & Gould P.C., or any of its attorneys.

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Merchant & Gould P.C.
P.O. Box 2903
Minneapolis, MN 55402-0903

*2355
2*

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2	**Full Name Of Inventor**	**Family Name** Du Toit	**First Given Name** Cornelis	**Second Given Name** Frederik
0	**Residence & Citizenship**	**City** Ellicott City	**State or Foreign Country** Maryland	**Country of Citizenship** New Zealand
1	**Mailing Address**	**Address** 9941 Frederick Road	**City** Ellicott City	**State & Zip Code/Country** Maryland 21042/United States
Signature of Inventor 201:			**Date:**	

2	**Full Name Of Inventor**	**Family Name** Ehlen	**First Given Name** Mathias	**Second Given Name**
0	**Residence & Citizenship**	**City** Upper Hutt	**State or Foreign Country** New Zealand	**Country of Citizenship** The Netherlands
2	**Mailing Address**	**Address** 26 Forest Road, Pivehaven	**City** Upper Hutt	**State & Zip Code/Country** New Zealand
Signature of Inventor 202:			**Date:**	

2	**Full Name Of Inventor**	**Family Name** Tan	**First Given Name** Benjamin	**Second Given Name** Cristobal
0	**Residence & Citizenship**	**City** Wellington	**State or Foreign Country** New Zealand	**Country of Citizenship** New Zealand
3	**Mailing Address**	**Address** 3 Parson Glens, Karori	**City** Wellington	**State & Zip Code/Country** New Zealand
Signature of Inventor 203: X			**Date:** X 22-2-02	

2	**Full Name Of Inventor**	**Family Name** Thomson	**First Given Name** John	**Second Given Name** Heywood
0	**Residence & Citizenship**	**City** Wellington	**State or Foreign Country** New Zealand	**Country of Citizenship** New Zealand
4	**Mailing Address**	**Address** 29 Ferry Street, Seatoun	**City** Wellington	**State & Zip Code/Country** New Zealand
Signature of Inventor 204:			**Date:**	

Attorney Docket No. 8436.88USWO

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: VARIABLE PHASE SHIFTER

The specification of which
a. ☐ is attached hereto
b. ☒ was filed on November 20, 2001 as application serial no. 09/979586 and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. PCT/IB00/00739 filed May 22, 2000 and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

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a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**
New Zealand	335901	May 20, 1999	
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

I acknowledge the duty to disclose information that is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (reprinted below):

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim

or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

(e) In any continuation-in-part application, the duty under this section includes the duty to disclose to the Office all information known to the person to be material to patentability, as defined in paragraph (b) of this section, which became available betweer the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

Albrecht, John W.	Reg. No. 40,481	Leonard, Christopher J.	Reg. No. 41,940
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Batzli, Brian H.	Reg. No. 32,960	Mayfield, Denise L.	Reg. No. 33,732
Beard, John L.	Reg. No. 27,612	McDonald, Daniel W.	Reg. No. 32,044
Berns, John M.	Reg. No. 43,496	McIntyre, Jr., William F.	Reg. No. 44,921
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Clifford, John A.	Reg. No. 30,247	Pino, Mark J.	Reg. No. 43,858
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Daignault, Ronald A.	Reg. No. 25,968	Pytel, Melissa J.	Reg. No. 41,512
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Gould, John D.	Reg. No. 18,223	Stoll-DeBell, Kirstin L.	Reg. No. 43,164
Gregson, Richard	Reg. No. 41,804	Sullivan, Timothy	Reg. No. 47,981
Gresens, John J.	Reg. No. 33,112	Sumner, John P.	Reg. No. 29,114
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Jardine, John S.	Reg. No. P-48,835	Weaver, Paul L.	Reg. No. 48,640
Johns, Nicholas P.	Reg. No. 48,995	Welter, Paul A.	Reg. No. 20,890
Johnston, Scott W.	Reg. No. 39,721	Whipps, Brian	Reg. No. 43,261
Kadievitch, Natalie D.	Reg. No. 34,196	Whitaker, John E.	Reg. No. 42,222
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Kettelberger, Denise	Reg. No. 33,924	Williams, Douglas J.	Reg. No. 27,054
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Knearl, Homer L.	Reg. No. 21,197	Witt, Jonelle	Reg. No. 41,980
Kowalchyk, Alan W.	Reg. No. 31,535	Wong, Thomas S.	Reg. No. 48,577
Kowalchyk, Katherine M.	Reg. No. 36,848	Wu, Tong	Reg. No. 43,361
Lacy, Paul E.	Reg. No. 38,946	Young, Thomas	Reg. No. 25,796
Larson, James A.	Reg. No. 40,443	Zeuli, Anthony R.	Reg. No. 45,255

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Merchant & Gould P.C. to the contrary.

I understand that the execution of this document, and the grant of a power of attorney, does not in itself establish an attorney-client relationship between the undersigned and the law firm Merchant & Gould P.C., or any of its attorneys.

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Merchant & Gould P.C.
P.O. Box 2903
Minneapolis, MN 55402-0903

*2355
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2 0 1	**Full Name Of Inventor**	**Family Name** Du Toit	**First Given Name** Cornelis	**Second Given Name** Frederik
	Residence & Citizenship	**City** Ellicott City	**State or Foreign Country** Maryland	**Country of Citizenship** New Zealand
	Mailing Address	**Address** 9941 Frederick Road	**City** Ellicott City	**State & Zip Code/Country** Maryland 21042/United States
Signature of Inventor 201:			**Date:**	
2 0 2	**Full Name Of Inventor**	**Family Name** Ehlen	**First Given Name** Mathias	**Second Given Name**
	Residence & Citizenship	**City** Upper Hutt	**State or Foreign Country** New Zealand	**Country of Citizenship** The Netherlands
	Mailing Address	**Address** 26 Forest Road, Pinehaven	**City** Upper Hutt	**State & Zip Code/Country** New Zealand
Signature of Inventor 202:			**Date:** 26/02/2002	
2 0 3	**Full Name Of Inventor**	**Family Name** Tan	**First Given Name** Benjamin	**Second Given Name** Cristobal
	Residence & Citizenship	**City** Wellington	**State or Foreign Country** New Zealand	**Country of Citizenship** New Zealand
	Mailing Address	**Address** 3 Parson Glens, Karori	**City** Wellington	**State & Zip Code/Country** New Zealand
Signature of Inventor 203:			**Date:**	
2 0 4	**Full Name Of Inventor**	**Family Name** Thomson	**First Given Name** John	**Second Given Name** Heywood
	Residence & Citizenship	**City** Wellington	**State or Foreign Country** New Zealand	**Country of Citizenship** New Zealand
	Mailing Address	**Address** 29 Ferry Street, Seatoun	**City** Wellington	**State & Zip Code/Country** New Zealand
Signature of Inventor 204:			**Date:** 26/02/02	

Attorney Docket No. 8436.88USWO

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: VARIABLE PHASE SHIFTER

The specification of which
a. ☐ is attached hereto
b. ☒ was filed on November 20, 2001 as application serial no. 09/979586 and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. PCT/IB00/00739 filed May 22, 2000 and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**
New Zealand	335901	May 20, 1999	
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U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

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Larson, James A.	Reg. No. 40,443	Zeuli, Anthony R.	Reg. No. 45,255

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I understand that the execution of this document, and the grant of a power of attorney, does not in itself establish an attorney-client relationship between the undersigned and the law firm Merchant & Gould P.C., or any of its attorneys.

[redacted]

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Merchant & Gould P.C.
P.O. Box 2903
Minneapolis, MN 55402-0903

23552
23552
PATENT TRADEMARK OFFICE

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2 0 1	**Full Name Of Inventor**	**Family Name** Du Toit	**First Given Name** Cornelis	**Second Given Name** Frederik
	Residence & Citizenship	**City** Ellicott City MD	**State or Foreign Country** Maryland	**Country of Citizenship** New Zealand NZ
	Mailing Address	**Address** 9941 Frederick Road	**City** Ellicott City	**State & Zip Code/Country** Maryland 21042/United States
Signature of Inventor 201:			**Date:** 25 February 2002	
2 0 2	**Full Name Of Inventor**	**Family Name** Ehlen	**First Given Name** Mathias	**Second Given Name**
	Residence & Citizenship	**City** Upper Hutt	**State or Foreign Country** New Zealand	**Country of Citizenship** The Netherlands
	Mailing Address	**Address** 26 Forest Road, Pivehaven	**City** Upper Hutt	**State & Zip Code/Country** New Zealand
Signature of Inventor 202:			**Date:**	
2 0 3	**Full Name Of Inventor**	**Family Name** Tan	**First Given Name** Benjamin	**Second Given Name** Cristobal
	Residence & Citizenship	**City** Wellington	**State or Foreign Country** New Zealand	**Country of Citizenship** New Zealand
	Mailing Address	**Address** 3 Parson Glens, Karori	**City** Wellington	**State & Zip Code/Country** New Zealand
Signature of Inventor 203:			**Date:**	
2 0 4	**Full Name Of Inventor**	**Family Name** Thomson	**First Given Name** John	**Second Given Name** Heywood
	Residence & Citizenship	**City** Wellington	**State or Foreign Country** New Zealand	**Country of Citizenship** New Zealand
	Mailing Address	**Address** 29 Ferry Street, Seatoun	**City** Wellington	**State & Zip Code/Country** New Zealand
Signature of Inventor 204:			**Date:**	